RADIO and ELECTRONICS

JANUARY 1st, 1947

Included in this Issue:

AN EXPERIMENTAL 2-STAGE I.F. AMPLIFIER

TUBE DATA—THE EL33

THE RADEL 2-VALVE DRY-BATTERY AMPLIFIER

GEIGER-MUELLER COUNTERS

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RADIO and ELECTRONICS

Vol. 1, No. 10 January 1st, 1947

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CORRESPONDENCE

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A MATTER OF AERIALS

It is a far cry from the present-day supersonic heterodyne receiver (to give it its full title) to the crystal set of the 1920's; in fact, very few branches of technology can point to an advance equally great in so short a time. It is all the more regrettable on this account that so excellent a machine as a modern radio receiver should suffer so often from being improperly operated.

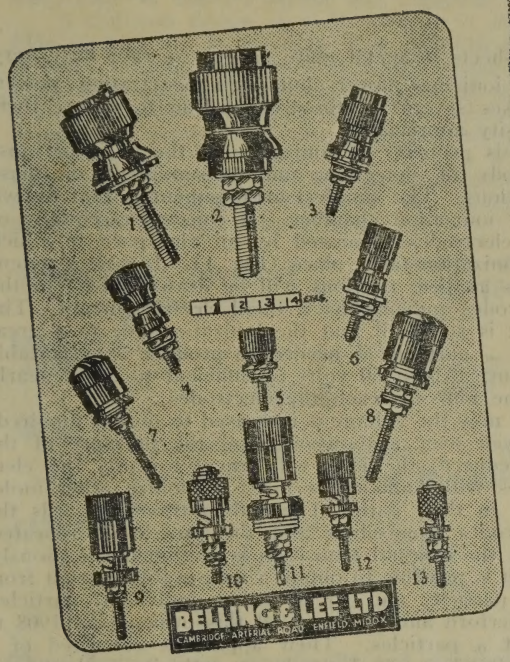
We refer, of course, to the common practice of using as an aerial nothing more than the few inches of wire usually provided by the manufacturer as a means of connecting a properly constructed aerial to the set. There is little doubt that the high sensitivity and excellent A.V.C. characteristics of modern receivers are responsible for the growth of this practice among set users, but there is a little more to it than this.

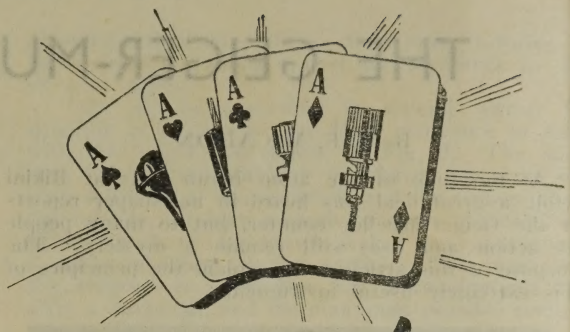
Some years ago, when high sensitivity with simultaneous stability was somewhat of a novelty to the public, it was a matter of pride to many owners that their sets would bring in this or that station "without an aerial." This attitude was seized upon by many salesmen and capitalized, not unnaturally, by making it a selling feature, with the inevitable result that other salesmen who may have known better were placed at a disadvantage. Once the idea has been implanted in the public mind that a set which apparently works quite well without an aerial is a better set than one which has a good aerial attached to it, it takes a very good salesman to convince the same public that this is a first-class fallacy. Thus, to this day, an idea persists in many quarters that an aerial is an unnecessary encumbrance!

It is only fair at this point to make clear that this mistaken idea has never taken root to any extent in country and semi-country districts. It is significant as one travels away from Wellington, Auckland or any of the four main centres, to note that the number of properly-constructed aerials visible from the road or train increases greatly in some kind of proportion to the distance travelled. True, this has something to do with the fact that most listeners seldom tune to anything more difficult to receive than their "local" stations, and that the country districts do not yet possess "local" coverage comparable with that which is supplied to the urban areas, but it illustrates our point very well, notwithstanding.

Although people do listen to the "locals" for the most part, there is always the odd occasion when purely local listening does not fill the bill, and it is at these times that the lack of a properly-constructed aerial shows up. If the listening public were technically-minded enough to ascribe a lack of good distant-station performance to the lack of an aerial, perhaps all would be well, but this is not the case and never will be. If interference-free reception of a certain station cannot be obtained up to the set-owner's expectation, the first thing he blames is the receiver, which for the industry is a bad thing. It is also a source of considerable trouble to those responsible for the quelling of interference which, by law, must be tracked down and suppressed if a complaint is made. Most important of all, of course, is the fact that the listener's own enjoyment is often unnecessarily reduced.

The novelty of distant reception has now worn off sufficiently to afford retailers no excuse, and certainly no advantage in minimising to their customers the necessity for a good aerial if they are to obtain the best result from their sets. In fact, the situation is now quite the reverse, and it must be to the advantage of listeners and trade alike for the true state of affairs to become publicised.





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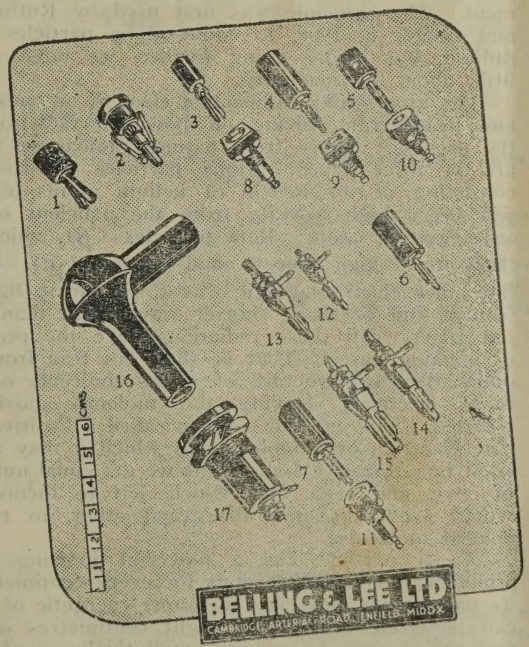
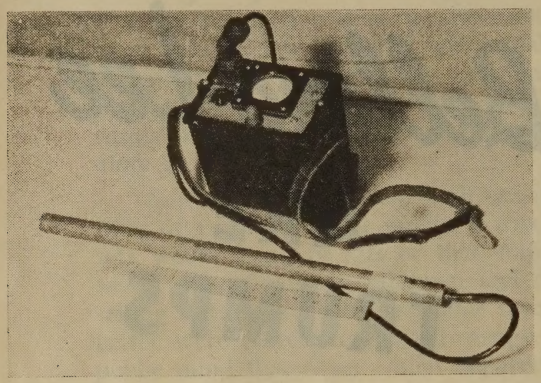


THE GEIGER-MUELLER COUNTER

By J. F. McCAHON

At the time of the atom bomb tests at Bikini Atoll, a great deal was heard in newspaper reports of the Geiger-Mueller counter, but to many people its action and uses still remain a mystery. The purpose of this article is to explain the principles of this extremely useful instrument.



A portable counting-meter, together with its Geiger-Mueller tube, which is enclosed in the brass tube in the foreground.

The G.M. counter is by no means a new development. The principle was first used by Rutherford and Geiger in 1908, to count alpha particles from radium, but before going further, we must say a little about Radioactivity.

The atoms of a radioactive element are unstable, and disintegrate, giving off powerful radiations in the process. Those from natural radioactive atoms are of three types: Alpha particles (written α), consisting of the neuclii of helium atoms, ejected with very high velocity from the neucleus of the disintegrating atom; Beta particles (β) which are electrons of high energy; and Gamma (γ). These latter are electromagnetic waves, similar to light or X-rays, but of much shorter wavelength than even the latter. All these radiations have the property of ionizing gases. That is, they can tear from the outer electron structure of a gas molecule one or more electrons, leaving the molecule positively charged. This molecule is then called a Positive Ion. The electron, or a molecule to which it may attach itself is a Negative Ion. Thus we get equal numbers of +ve. and −ve. ions which, left to themselves, would eventually neutralise each other, to reform neutral molecules.

An α particle has a powerful ionizing effect producing about 100,000 ions for every centimeter of its path in air, but even the most energetic of them can penetrate only about eight centimetres of air, and are stopped by a very small thickness of solid matter. β particles have a much smaller ionizing power, and correspondingly greater range. It takes about 100 times the thickness of solid matter to stop them than that required for α's. They can penetrate thin sheets of metal quite easily. γ rays have very little ionizing power, but high penetrating power. It takes several centimetres of lead to reduce their intensity appreciably.

This property of ionization is the basis of most methods of detection and measurement of these radiations. The simplest arrangement is that known as an ionization chamber. It consists essentially of two electrodes separated by an air space in which the ionization takes place (Fig. 1). If now a potential is applied, the ions will be drawn across to the electrodes and produce a small electric current. The effect is so small that the ionization due to a great many α particles is needed to produce a measurable current. About 50 volts is sufficient to cause nearly all the ions to reach the electrodes.

If now the voltage is increased to several hundreds or even over a thousand, and the pressure of the air reduced, the ions will travel towards the electrodes with sufficient velocity to ionize other molecules in their path. These then travel towards the electrodes themselves and the process is repeated. Thus the original ionization is amplified enormously, and it is possible to obtain a measurable current from one particle, and so to count individual particles. Rutherford and Geiger used this principle in 1908 to count α particles. Their apparatus consisted of a cylindrical −ve. electrode, or cathode, in the centre of which was the anode, or positive electrode, in the form of a fine wire. The tube contained gas at low pressure, and the α's were admitted through a thin

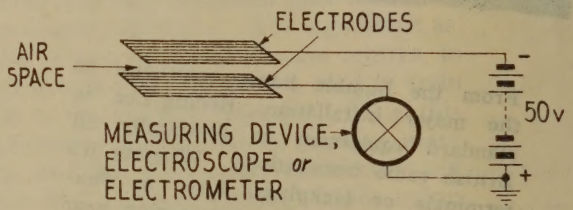


FIG.1

Showing the arrangement of a simple ionisation chamber, the forerunner of modern counting tubes.

mica window. There were no valve amplifiers available at that time, so an electrometer was used to detect the pulses of current, which had to be counted individually by an observer. This was just as laborious a method as that of counting the scintillations of light which the particles cause on a screen of zinc sulphide, and as the latter method was simpler to set up, it was generally used.

By the 1920's the development of vacuum tubes had made it possible to devise circuits which would record the pulses automatically, and the counter came into general use. From that time on a large amount of research has been done on the construction and use of counters. In 1928 Geiger and Mueller pointed out the advantages of cylindrical counters over other types. This type of counter is now generally known as a Geiger-Mueller counter. About 1930 the development of coincidence counting circuits increased the usefulness of G.M. counters still further, especi-

ally in the field of cosmic ray research. It was not until about 1939 that an accurate picture of the mechanism of counter action was obtained.

A common design of G.M. counter is shown in Figs. 2 and 3. It consists of a cylindrical metal cathode, through the centre of which a fine wire is stretched as anode. The whole system is sealed in a glass envelope containing gas at low pressure. A potential of about 1,000 volts is applied between the electrodes, with the cylinder — ve. It can be shown that the electric field between the two electrodes is most intense close to the wire, the effect being greater the finer the wire is made.

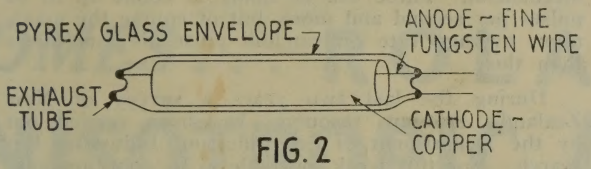


FIG. 2

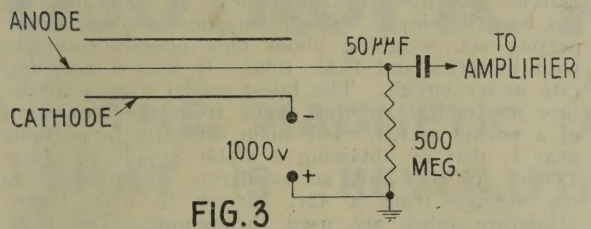


FIG. 3

These figures show, structurally and electrically, the make-up of a Geiger-Mueller counting tube.

Suppose now that a molecule of the gas between the electrodes becomes ionized. The negative ion is initially a free electron which is immediately drawn towards the anode. Collisions with gas molecules prevent its gaining any great velocity until it reaches the region of intense field near the centre of the tube. Here the electron gains enough energy between collisions to ionize the molecules with which it collides. The electrons thus produced, cause more ionization as previously described. Thus a single electron has produced an avalanche of others which travel with it towards the central wire. During this process, a small amount of light is produced, some of which is of short enough wavelength to eject electrons from the cathode surface; a process similar to that in a photo-electric cell. These are then drawn to the anode and the discharge spreads through the whole length of the tube. It may seem that we have now reached a state of steady discharge, but another effect now comes into play which prevents this.

We have up till now, neglected the + ve. ions produced in the discharge. They are thousands of times heavier than the electrons and so far have hardly moved from the position they were in when formed. They form a sheath round the anode, and being themselves positively charged, reduce the field intensity close to it, and prevent the formation of further ions. All the electrons are then drawn to the anode and the discharge stops. The time taken to complete this process is of the order of one ten-millionth of a second, but in that time as many as a thousand million electrons may have reached the wire. The + ve. ions now move out to the cathode relatively slowly, and on striking it, may liberate secondary electrons. These then move towards the anode, and we would expect the discharge to start all over again.

This can be prevented in several ways. The simplest is to use a very high resistance in series with the anode, as shown in Fig. 3. The anode then has a considerable — ve. charge for some time after a discharge has occurred, and the voltage across the tube is not high enough to cause a second one. When the charge has slowly leaked away, the counter is ready to detect another particle. This means that the counter is insensitive for a considerable time after a discharge, and the maximum possible counting rate is limited.

For this reason, vacuum tube quenching circuits with short recovery time are often used. These are of many types. The Neher-Harper circuit is shown in Fig. 4. The 6J7 tube is normally not conducting and the full voltage is applied across the counter, but if a discharge occurs, point A becomes more + ve., the tube conducts, and point B drops to a low potential. This prevents a second discharge, but as soon as the charge leaks off the grid through the comparatively low resistance R, the tube recovers its sensitive condition.

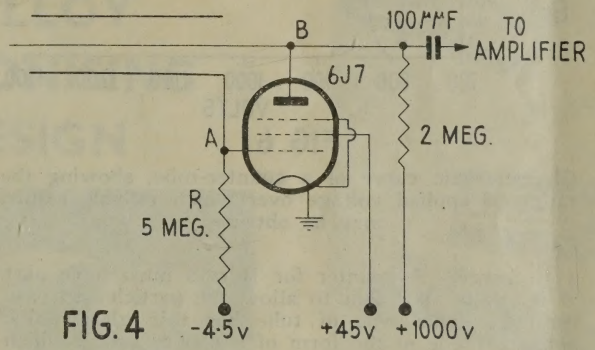


FIG. 4

The Neher-Harper circuit, which has a short recovery period.

A third method of preventing multiple discharges is to incorporate in the gas filling of the tube a small amount of organic vapour, such as alcohol or ether. This forms a molecular layer on the cathode which prevents the ejection of secondary electrons.

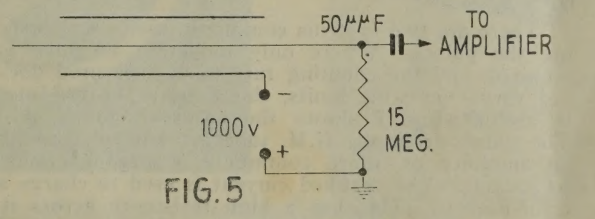


FIG. 5

The circuit used with a self-quenching counter-tube.

These, commonly known as self-quenching counters, work well with the simple circuit of Fig. 5, and are very convenient for light portable apparatus, but are not as accurate as the externally quenched type, as their characteristics change slowly with time.

Fig. 6 shows a typical characteristic curve of a counter. It is a graph of counts per minute, against

voltage, the intensity of radiation being kept constant. Up to the point A, no counts occur. Then from A to B the counting rate increases rapidly. The region B to C is called the "Plateau" and is the range of voltage over which the counter will give reliable results. Above C spurious counts start to appear. These are discharges which occur spontaneously, causing the counting rate to rise.

The design of counters varies considerably according to the type of radiation they are to detect. The commonest type is the γ ray counter. As γ rays have great penetrating power, these can be built with thick walls, and, in use, are often enclosed in metal cases. The direct ionizing effect of γ rays is so small that, by themselves, they would very seldom produce a count, but in passing through solids they can eject electrons, or secondary B rays. These are produced from the metal of the cathode and cause

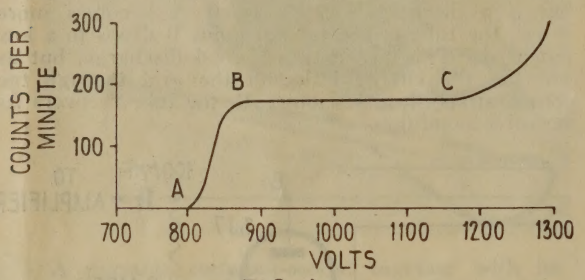


FIG. 6

Characteristic curve of a counter-tube, showing the range of applied voltage over which reliable results may be obtained.

a discharge. A counter for B rays must have part of its walls very thin to allow the particles to pass through. This type of tube has thin glass walls, and a cathode in the form of a copper spiral, which form also reduces the response to γ rays. For cosmic rays a counter similar to those for γ rays is suitable, as cosmic rays are also of high penetration. In this application two or more counters are often used together with a "Coincidence" circuit, which records a count only when they all discharge simultaneously. This gives a directional effect, as a particle must pass through both tubes, to be recorded.

There are two systems commonly used for recording the pulses. Where only moderate accuracy is required, and the counting rate to be measured does not vary over wide limits, the Counting-Rate-Meter is useful. Fig. 7 shows the basic circuit of this. The pulses from the G.M. tube are applied through an amplifier or, more commonly, a trigger circuit, to a diode. The rectified current is used to charge a condenser C. This has a high resistance across it, and the voltage it finally reaches depends on the rate of arrival of pulses. This voltage can then be applied to the grid of another tube, with a meter in the plate circuit, calibrated to read counting rate directly. As the pulses do not come at a regular rate, but are spaced at purely random intervals, it is necessary to use a large condenser to smooth out the variations in counting rate, and give a mean value. This means that the meter takes some time to come to its final reading. At about 200 counts per minute, it may take up to three minutes to come to rest.

In laboratories and factories where radioactive materials are used, a circuit of this sort can easily be arranged to give an alarm if the radiation reaches a dangerous intensity.

A system giving greater accuracy and able to handle a wider range of counting rates, is the mechanical counter. This is essentially an electromagnet energised from the pulse amplifier, and driving a pointer round a dial by means of a ratchet mechanism. These can be made to count up to 60 pulses per second and more, but of course the maximum average rate on random pulses is much less than this.

During the last two years a survey of New Zealand's uranium resources has been carried out by the Department of Scientific and Industrial Research. For this work, portable G.M. counting gear has been developed. The photograph shows a prospecting set, weighing about nine pounds complete with batteries and G.M. tube. It uses a counting rate meter circuit. The latest model uses a miniature mechanical counter, made from the movement of a pocket watch. The main difficulty in portable gear is that of obtaining a stable supply of about 1,000v. In this unit, an oscillating circuit steps up the voltage from a 45v. battery to over 1,000v. Miniature tubes are used throughout. The G.M. tube, along with its leak resistance and coupling condenser, is in the brass sheath in the front of the picture.

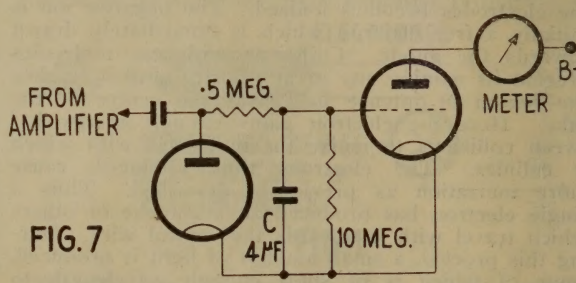


FIG. 7

The basic circuit of the counting-rate meter. Though useful, this circuit does not give as accurate results as an electro-mechanical counter operated by the Geiger-Mueller tube.

As well as the applications mentioned so far, G.M. tubes are used in all branches of atomic and nuclear physics, including work on atomic energy; in X-ray work; in some systems of metal testing, using γ rays; and in conjunction with artificial radioactive elements, in the new science of tracer chemistry. A large number of the safety and warning devices used at Bikini depended on G.M. counters. They are also used, more than one might expect, to trace lost radium needles in hospitals.

We have now touched at least the fringe of the subject; an extremely interesting one, and, expanding at its present rate, likely to become more so in the future.

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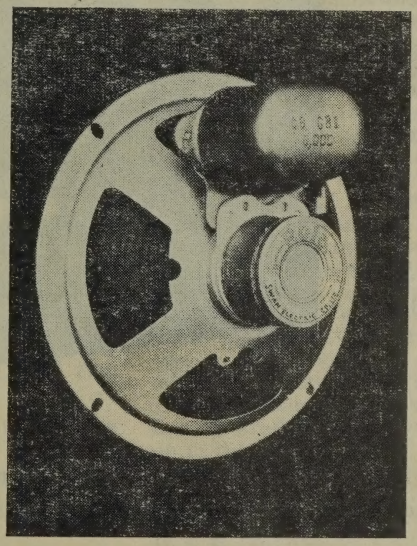

Now this new Anisotropic Alnico, so powerful that a magnet carried in the vest pocket can lift a hundredweight, comes to the radio industry in the form of lighter, more compact and more efficient loudspeakers.

Very shortly these new speakers, which are destined to render obsolete old type permanent magnet and electrodynamic speakers, will be available for the general resale trade. Watch for further announcements of the new Rola models using Anisotropic Alnico.

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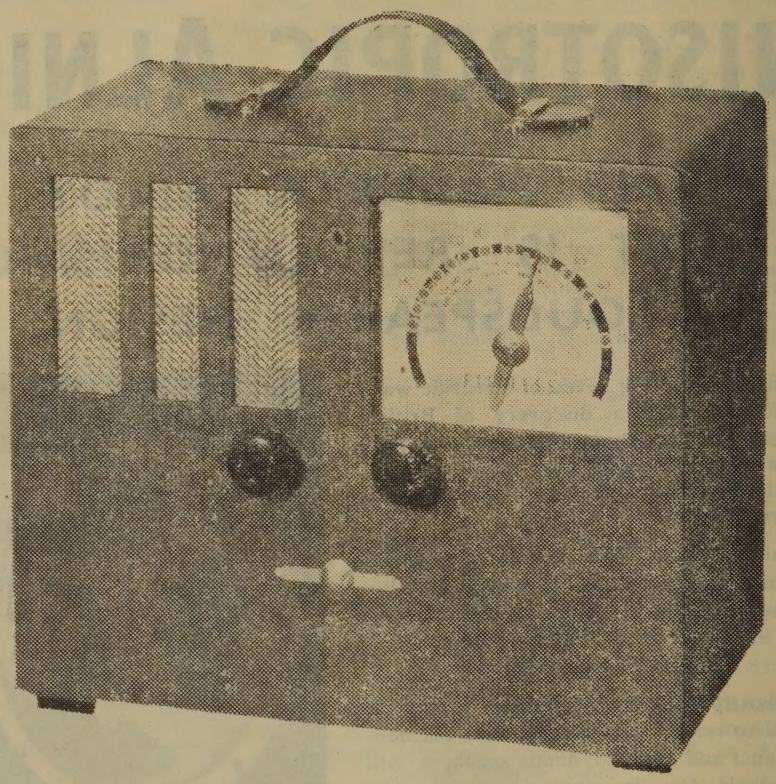

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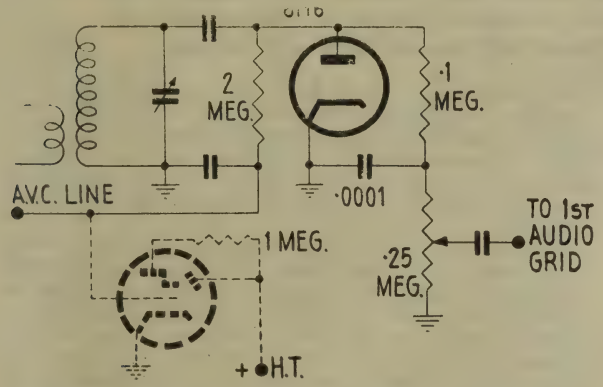
QUESTIONS AND ANSWERS

Mr. R. Baker, Petone, gives us the circuit of the diode detector and A.V.C. tube which he is using in a nine-valve T.R.F. receiver, and wishes to know how a magic eye tuning indicator should be attached to the circuit.



Adding a "magic eye" tube to the diode detector of a T.R.F. receiver.

Herewith is the original circuit, with the magic eye additions shown dotted. Since simple A.V.C. is used in this circuit, the magic eye can be operated from the A.V.C. line, as shown. The A.V.C. operates in this case even on the weakest signals, so that the same holds for the magic eye. In a circuit where delayed A.V.C. is used, the eye should be operated from the detector diode, rather than the A.V.C. diode, so that all signals may operate the eye, and not only those strong enough to work the A.V.C.

* * *

C.J.T., Auckland, writes with several queries about the "High Quality Broadcast Tuner" which appeared in our December issue. He asks:

(1) Why is a 6K8 and an intermediate frequency used if there is no amplification following?

(2) If fidelity is the main requirement, why not use a T.R.F. receiver using, say, two EF38's?

(3) Is not the 6K8 a noisy tube to use where high quality is desired?

(4) Should there not be more filtering in the output of the infinite impedance detector?

Taking C.J.T.'s questions in order:—

(1) and (2) These two questions are really bound up together. One good reason for preferring a superhet circuit is that two stages of T.R.F. are more difficult to make quite free from regeneration, which, though it may not cause oscillation, can easily increase the selectivity to the point where the expected wide bandwidth is not realised. On the other hand, converting to an intermediate frequency gives inherently greater stability, and has the big advantage that the bandwidth is almost constant all over the broadcast band—a thing that by no means occurs with an ordinary T.R.F. amplifier.

(3) Although the 6K8 may be called "noisy" as mixer tubes go, the term is purely a relative one, and has no significance whatever in the reception of local signals, where set noise cannot become a problem, owing to the low gain of the tuner.

(4) An R-C filter is often found in infinite impedance detector circuits in addition to the load bypass condenser, but this is not strictly necessary, particularly if a shielded output lead is used from the tuner to the amplifier.

* * *

Mr. D. Young, Wellington, has purchased a multi-range meter which has a scale of decibels from -12 to $+16$, based on a zero level of 6 milli-watts into a 500-ohm load. He wishes to know how the meter can be made to indicate decibels with loads other than 500 ohms.

It appears from Mr. Young's letter that he is not quite clear as to the meaning of the decibel and the exact significance of the zero level used in connection with this unit. This is a question that puzzles many radio enthusiasts, so that a few words on this subject will not be out of place. First, the decibel is a unit which indicates a ratio between two power levels. It has no meaning at all unless a reference level is stated. Secondly, two power levels cannot be compared by means of the decibel notation, unless they are found in circuits having identical impedances. One way of establishing a reference level is to state the power which is considered as the zero level. In the case of Mr. Young's meter this has been given as 6 milliwatts, or 1.73 volts across an impedance of 500 ohms. The latter is simply another way of saying 6 milliwatts, as simple calculation will show. The reason for 6 milli-watts being chosen and for the alternative specification of 1.73 volts into 500 ohms, is that in telephone and broadcast practice practically all amplifier outputs are transformed to an impedance of 500 ohms, and because 6 milli-watts was found to be a suitable level in a 500-ohm circuit for the operation of telephones. For example, the line which departs from 2YA studio for the transmitter at Titahi Bay carries the programme at a normal maximum level of 6 milli-watts in the 500-ohm line which is used. If Mr. Young's meter were connected across this line he would find, on peaks, the needle would swing up to the point marked 0 Db. However, most servicemen and amateur enthusiasts have little use for output impedances of 500 ohms, and are much more interested in impedances from 2000 ohms to 20,000 ohms. If it is required to use the meter as an indicator of actual power level, it will be necessary to have a transformer which will convert the actual load impedance to one of 500 ohms before applying the output to the meter. In addition, a non-inductive load would have to be placed across the 500-ohm secondary, of 500 ohms resistance. However, if a relative indication only is required, no transformer need be used as the scale on the meter will indicate decibels above or below the zero level whether the latter is 6 milli-watts or not.

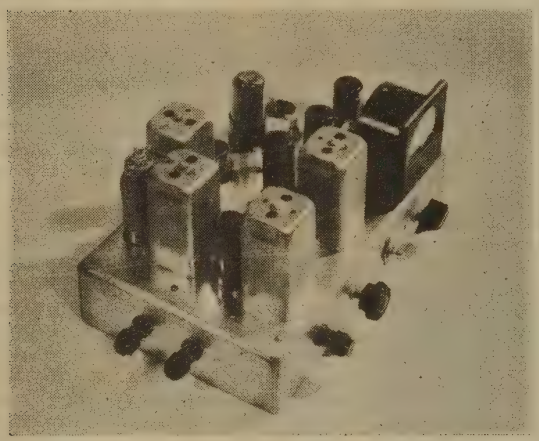
AN EXPERIMENTAL TWO-STAGE I.F. AMPLIFIER

This article describes an experimental unit which was built in our laboratory and which, it was felt, provided a number of interesting constructional features. The design given here could well be incorporated as it stands in a complete receiver, or could be built, as in this instance, for use in experimental work with various "front end" circuits.

SPECIAL FEATURES

The features of this particular unit which may commend it to those in search of circuits are:—

(1) Very high sensitivity.
(2) High stability if properly constructed.
(3) Gain control either manual or automatic, or a combination of the two.
(4) Very effective A.V.C. through the use of a fairly high delay voltage.



General view of the experimental amplifier. The meter, unnecessary in most applications, was included in the prototype constructed in our laboratory to act as a V.T. volt-meter for taking gain measurements, etc.

(5) An improved B.F.O. circuit with a pre-set amplitude adjustment. This enables the B.F.O. output to be adjusted for best signal-to-noise ratio on C.W. signals.
(6) A.V.C.-B.F.O. circuit so arranged that, if desired, A.V.C. can be used successfully with C.W. signals.
(7) Cathode follower stage after the 2nd detector. This is an excellent arrangement where it is desired to feed the audio output to a separate amplifier, since it gives the low output impedmakes it possible for the two units to be ance necessary to avoid induction hum, and separated by some distance if desired. It also minimises 2nd detector distortion by virtue of its high input impedance.

WHY TWO STAGES?

A notable fact concerning amateur-constructed superheterodyne receivers is that by far the majority of them employ only one stage of I.F. amplification, with or without regeneration either in the I.F. stage itself, or in the second detector. If the circuits of a number of high-class commercial communications receivers are studied, the reverse situation is found to exist. Regeneration is never used, and the majority have two stages of I.F. What then is the reason for this difference between amateur and commercial practice?

In reality there are a number of reasons. First, two stages are much more difficult to make stable than one stage, which means that, to an amateur constructor, there is much more danger of his set misbehaving if he designs it with two stages of I.F. Secondly, for many purposes, the gain and selectivity of a single stage, especially if it incorporates regeneration, are quite sufficient for many purposes. Thirdly, an amateur receiver may not necessarily require a second stage where a commercial job does. For example, the commercial set more often employs a crystal filter which, when in use, makes a second stage of I.F. very desirable, if not absolutely necessary.

Of all these reasons, perhaps the most important from the amateur constructor's point of view is the first. If his set, when completed, will not "sit down" he is faced with a great deal of trouble in making it do so, or even the possibility that he may not be able to do so at all. As a result, the receiver may never work as it should. Rather than run into trouble in this way, many constructors prefer to forego the extra gain and selectivity afforded by a two-stage I.F. amplifier, and stick to the usual single-stage circuit, with a reasonable assurance that it will perform properly.

However, for some purposes, the extra gain and selectivity of the two-stage arrangement are well worth a little trouble to obtain without resorting to regeneration, with its attendant disadvantages. One such occasion, as suggested in our recent article on the design of amateur-band receivers, is when an infinite impedance mixer is used in the receiver. In this case, the lack of valve-gain in the mixer stage makes desirable a higher gain in the I.F. portion of the set, and in addition allows much more than normal I.F. gain to be usefully employed on account of the low mixer noise level.

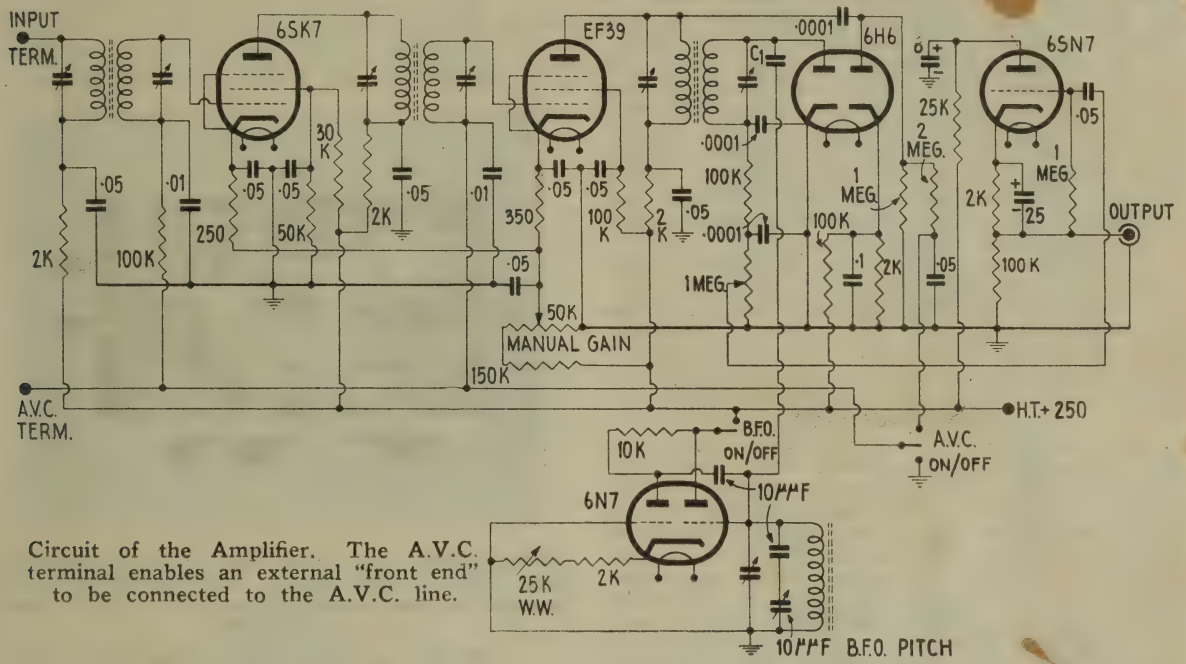
Therefore, this amplifier can be regarded as the first stage in the design by "Radio and Electronics" of a series of receivers suitable for amateur use, and embodying some of the principles laid down in the article referred to above.

THE CIRCUIT IN DETAIL

Bypassing and Decoupling:

Apart from the special features mentioned earlier in this article, several points are worthy of note. Most important is the comprehensive decoupling employed at all necessary points. The cathodes, screens, and plate return leads to both I.F. stages

are all separately decoupled. In a circuit of this kind, it is inadvisable to use a common screen supply network with only a single bypass condenser, if stability is to be assured. It will be noted also, that the primary winding of the first I.F. transformer is also connected through a decoupling filter to H.T. + so as to provide H.T. for the mixer, which does not appear on the circuit, and whose plate is connected to the input terminal.



Circuit of the Amplifier. The A.V.C. terminal enables an external "front end" to be connected to the A.V.C. line.

It would appear that some points on the circuit have been bypassed twice, and that one condenser could be omitted without affecting the operating. The first point is quite true. Double bypassing is used, for example, in the cathode circuit containing the manual gain control. However, it is not necessarily true that if one of the condensers is removed, the circuit will be stable, so that what seems an extraordinary precaution is only good practice. Using the example of the cathode circuit by way of illustration, the 6SK7 and EF39 cathodes are first of all bypassed at the socket pins. The bias resistors are mounted at this point also, and leads from each are run over quite a long distance to the manual gain control on the front of the chassis. Here, right at the moving arm of the potentiometer, is another bypass condenser that might seem superfluous. It is not, however, for although the cathodes are bypassed, the leads to the control could have R.F. potentials developed upon them through their proximity to the rest of the wiring. If this were to occur, the leads could cause undesired coupling between quite different parts of the circuit, resulting in instability or even incurable oscillation. The 0.05 mfd. condenser at the control ensures that this effect is minimised by earthing these leads at each end.

A similar precaution may be seen in the A.V.C. circuit, which even in single-stage amplifiers is sometimes a cause of instability through inadequate bypassing. Here, a 0.01 mfd. condenser is used right at the "cold" end of the second I.F. transformer's secondary, in spite of the fact that this point is already bypassed to earth by the 0.05 mfd. condenser in the A.V.C. filter which is interposed between the A.V.C. diode and the A.V.C. on/off switch. This ensures that when the A.V.C. is on, the comparatively long lead from the switch to the second I.F. transformer is bypassed at each end.

The plate decoupling filters should on no account be omitted, for they are strictly necessary in a multi-stage amplifier.

B.F.O. Circuit:

This circuit has been used before in "Radio and Electronics," but not as a beat frequency oscillator, for which it is very well suited, as it is a two-terminal oscillator. That is, no tickler winding or any other connection to the tuned circuit is necessary. The B.F.O. coil is therefore made from an iron-cored I.F. transformer by removing one of the windings. In the transformer used, the former was sawn off midway between the two windings. The iron dust cores in this case were held together at the correct spacing by a match stick which passed through small holes in the cores, and to which the latter were fixed with wax. When the former is sawn through, the match stick is cut also, and the core may fall out from inside the cardboard former. All that is necessary is to fix it back in place with some of the wax from round the unused winding. The leads from the now unused trimmer are unsoldered, and the coil is replaced in its can, ready for wiring up.

The value of the B.F.O. coupling condenser C_1 has not been specified on the circuit diagram. This is because its value is very small—only a few micro-microfarads—and the condenser is made by twisting together the ends of two pieces of hook-up wire for

a distance of half an inch or less. The lead to the B.F.O. circuit should be shielded. It is important that C_1 should be very small, so that the B.F.O. tuning control will have as little effect as possible on the tuning of the diode winding of the third I.F. transformer.

Amplitude Control:

The 25k. wire-wound potentiometer in the cathode of the 6N7 is used as a B.F.O. output control. It should be set to give a somewhat greater voltage at the detector diode than does the signal, if the best signal-to-noise ratio is to be realised for C.W. signals. As its setting will influence to some extent the frequency of the B.F.O., it is as well, after each trial setting, to reset the main B.F.O. trimmer, the pitch control condenser being at centre scale. An alternative connection between the 2nd detector and the B.F.O. would be to take the output from the B.F.O. cathode rather than the tuned circuit. This connection should give additional protection against interaction between the two tuned circuits.

The main point about setting the B.F.O. output control is to see that the oscillator is running at as low output as possible, consistent with obtaining enough amplitude at the 2nd detector. This idea helps to increase the stability of the B.F.O., and at the same time minimises harmonics, which can cause spurious signals if their amplitude is too high.

CONSTRUCTION

The construction of the unit can be seen from the accompanying photographs. The input I.F. transformer is at the left-hand front corner of the chassis. The 6SK7 is immediately behind this, and the layout follows the circuit to the back of the chassis, where the EF39 can be seen in the corner. After this, the layout goes from left to right along the back of the chassis, the order of parts being EF39, 3rd I.F. transformer, 6H6, 6SN7, and a spare socket for possible additions. The can in the centre front of the chassis is the B.F.O. coil, and directly behind it is the 6N7. The meter and the remaining two tubes are not included in the circuit diagram, as they merely form a built-in V.T. voltmeter, which measures D.C. volts developed across the detector diode load. They were incorporated in our case as the unit is a laboratory instrument rather than part of a receiver, and are certainly not necessary to the operation of the I.F. unit.

The layout shown here need not be rigidly adhered to, though the parts should always be arranged in the natural sequence of the circuit. This layout has much to recommend it in that, although it turns a right-angled corner at the back of the chassis, it still enables short and direct leads to be run where this is important, and keeps the input end fairly well spaced from the output end of the circuit.

POINTS FOR STABLE OPERATION

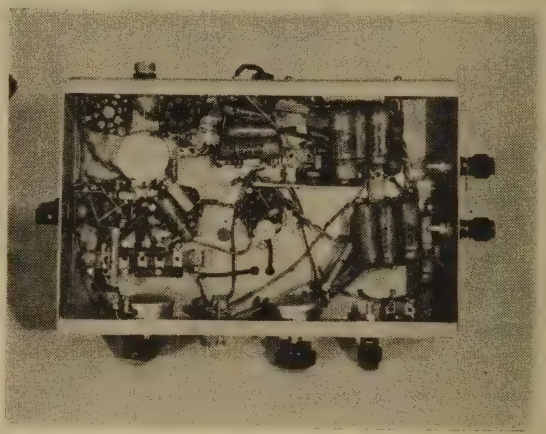
The successful achievement of stability in an amplifier of this sort calls for proper constructional procedure, which is just as important as a good circuit. However good the circuit may be electrically, the unit will be unstable unless the proper precautions are taken. In this case, the fact that the amplifier "sits down" is due just as much to the manner in which the wiring is carried out as to the use of proper decoupling circuits.

There are a few simple rules which, if followed, can scarcely fail to give the desired result.

(1) All bypass condensers belonging to one stage **must** be earthed at the same point on the chassis. This goes equally for the 6H6 as for the two I.F. stages.

(2) In wiring up the 6SK7 circuit, the manufacturer's recommendation that the grid and plate pins of the socket should be shielded by laying the screen bypass condenser across the valve socket must be carried out.

(3) Just as important as these two points, is the proper connection of bypass condensers so that the outside foil is earthed. All paper condensers these days have the end which connects to the outside foil clearly marked.



Under-chassis view. The EF39 is in the top right-hand corner of this picture. The components in the left-hand bottom corner are concerned with the built-in V.T.V.M.

(4) All decoupling filter condensers and resistors must be wired into the circuit as close as possible to the point which is to be decoupled. For instance, the plate decoupling filters of 0.05 mfd. and 2k. must be placed right where the lead from the I.F. transformer comes through the chassis.

(5) The plate supply leads, A.V.C. line, etc., after the places where they are decoupled, are run as close to the chassis as possible, and as far as possible from leads carrying signal.

(6) Valve sockets and I.F. transformers are mounted in the position shown, but care is necessary in fixing which way round they are turned, so that leads fall naturally into place, with as few cross-overs as possible. This ensures that the leads carrying the signal are as short and direct as possible.

Some of these points can be seen from the under-chassis photograph. The compact groups of bypass condensers belonging to the individual I.F. stages, and all earthed to the same point, can be seen quite easily.

SHIELDING

In any high-gain amplifier, even if all the above points are rigidly followed, there is still a possibility of feedback, and oscillation, especially where the construction is fairly compact. The under-chassis photograph shows that a small baffle-shield has been used in this case, and it was found to be absolutely

necessary. Without it, the amplifier oscillated, simply because of its extremely high gain, and because the output is only a few inches from the input end. However, in building the original, this was anticipated, and space was left so that, if necessary, a baffle-shield could be installed after the wiring was completed, extending right to the side of the chassis. As it was, the small shield shown turned out to be all that was necessary to render the amplifier perfectly stable.

It may be found necessary to enclose the wiring of the B.F.O. in a baffle-shield in order to keep its output from entering the I.F. stages by stray coupling. This was not done in the original model, but would have been necessary but for the B.F.O. amplitude control.

GAIN

The gain of the amplifier when working "flat-out" is very high indeed. This is only to be expected when the tube line-up and the use of iron-cored I.F. transformers are taken into account. The 6SK7 has a mutual conductance of 2 ma./v.—44 per cent. higher than that of the more usually used 6K7—while the mutal conductance of the EF39 is even higher, being 2.2 ma./v. This being the case, higher than normal gain for two stages is only to be expected. The measured gain was 71,000, or 99 db. A signal of 10 microvolts at the input gave an R.F. output of 0.71v. at the secondary of the final I.F. transformer.

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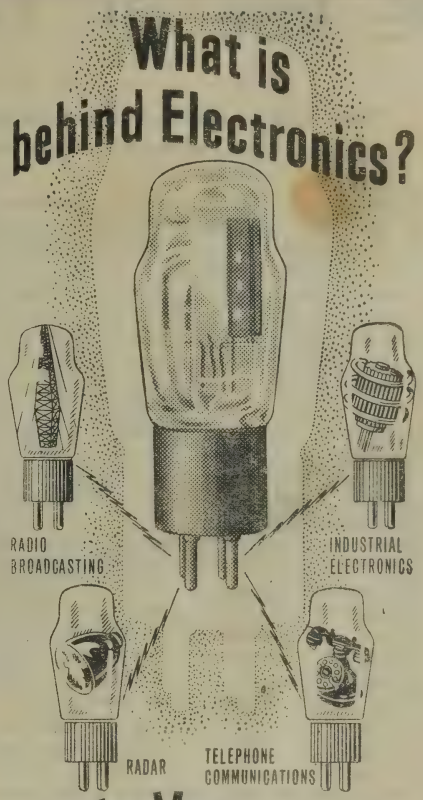

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THE RISE OF THE ELECTRONICS AGE

By H. LACEY HAWKINS

This article sketches the remarkable development of Fleming's key invention of the Thermionic Valve into a vast and complex modern industry.

The establishment of radio as a commonplace in the lives of most civilised peoples is due entirely to the fact that the mind of man has conceived and developed a device consisting of some wires and metal plates contained in a glass envelope, called a "thermionic valve." Therefore the story of the amazing achievements of the last forty years in radio and its wide applications commences with the invention, by John Ambrose Fleming, of that remarkable instrument.

This scientist made the "trifling" observation of the blackening of the glass bulb of an electric lamp, occurring when the carbon filament burnt out. Pursuing his investigations, Fleming noticed a thin line of undiscoloured glass lying in the plane of the unburnt section of the filament. "It was obvious to me," he said, "that the unbroken part of the filament acted as a screen to that particular line of clear glass, and that the discharge from the overheated point of the filament bombarded the remainder of the bulb with molecules of carbon or vaporised metal shot out in straight lines." The results of his experiments in 1882 and 1883 proved that he was right.

It was in 1883 that Edison, most prolific of American inventors, investigated another curious phenomenon. He, too, had noticed the blackening effect when a carbon filament burned out, and subsequently made one of the most inspired experiments in scientific history. Coating the outside surface of a lamp with thin metal foil, he connected it, through a sensitive galvanometer, to the positive terminal of the filament. As soon as the lamp was switched on the galvanometer needle moved! This meant that a small current was passing from the hot filament, through space to the envelope, then through the glass itself, to the foil outside.

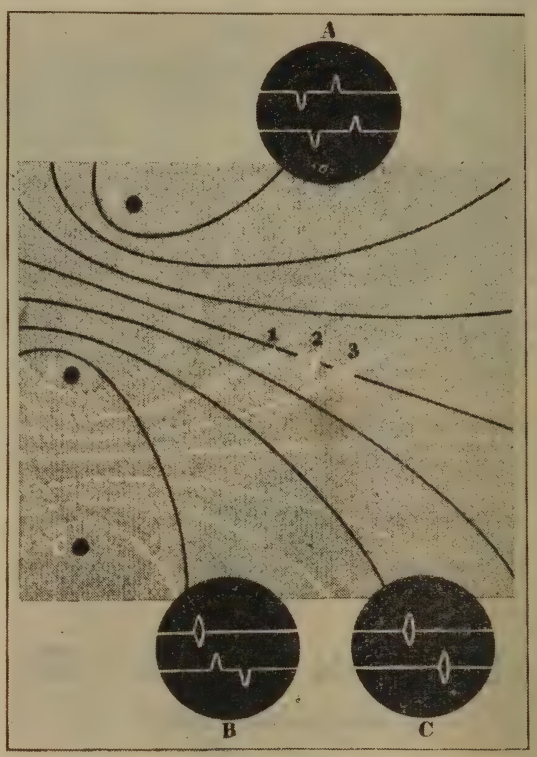
Edison reversed the connections. No current flowed. Thus was observed a phenomenon upon which the modern electronics industry is based. The "Edison Effect," as it was called, started a new chapter in the progress of science.

Fleming turns an Academic Discovery into a Practical Invention

Edison failed immediately to recognise the possibilities of his discovery, though he continued his investigations. Other scientists did likewise; and it was the Edison effect which led Fleming to his invention of the first "thermionic valve," forerunner of all that vast range of wonderful radio and other tubes in use to-day.

It is significant that Fleming made this great stride forward with the special objective of finding a better "detector" of wireless waves. Some special carbon filament lamps were made for him, in which two small metal plates were placed within the bulb. By connecting these plates and the filament in an alternating current circuit containing a galvanometer, he found that the lamp worked as a rectifier of alternating currents; that is, it converted a current which reversed its direction at very short intervals into a current running in one direction only.

The "diode valve", so called because it had only two electrodes—the filament (or cathode), and the plate (or anode)—was adopted as the rectifier for the high-frequency alternating currents used in early radio telegraphy. Fleming realised at once that, by substituting for the small plates a metal cylinder completely surrounding the filament, he could collect **all** the electrons emitted from the filament, and thus increase efficiency; and in this form the Fleming



"Gee"—Navigation by Radar. "A" is a master station sending out a series of rapidly repeated pulses by radio, while "B" and "C" are "slave" stations also transmitting similar pulses in step with "A." All points at which the pulses from "A" and "B" arrive simultaneously form, when joined together, the black lines in this diagram. The rapid succession of pulses is shown on the navigator's Radar instrument as a loop or "blip" on a horizontal track (see inserts). When the aircraft is in position 1, both pairs of blips are out of line, but as soon as the navigator has brought the plane to position 2 the two upper blips are in line, and he knows that he is somewhere along one of the black lines. He continues course along this line. When he reaches position 3 BOTH pairs of blips are in line and he therefore knows he is at a point where the black line crosses the white dotted one. In this way he obtains a very accurate check on his position by referring to his chart.

thermionic valve was used extensively by the Marconi Telegraph Company as a standard detector.

To a brilliant young American goes the honour for the next important advance. Lee de Forest, whilst at Yale University, had read a prophetic article by Sir William Crookes. He decided to make "wireless telephoning" his objective, and began a series of experiments, working mainly on the idea of a hot gas or flame detector. This scheme ultimately proved to be impracticable; but, full of confidence and determination, he went to New York and there met Abraham White, with whom he organised a company, reported to have been capitalised at three million dollars, called the De Forest Wireless Telegraph Company.

One object of the venture was to beat Marconi, who had come to New York to transmit wireless bulletins on the American Cup Races. Unfortunately, however, the De Forest Company collapsed some years later, and the young engineer returned to the problem of improving Fleming's valve detector, and of making it into an amplifier of signals.

He conceived the idea of adding a "trigger" device which would control the flow of electrons between filament (cathode) and plate (anode). A piece of platinum wire, wound in zig-zag form, was placed in the space between the two electrodes, which were connected to a battery to increase the electron flow between them. When a small negative charge was given to the platinum wire "grid" a considerable reduction took place in the electronic current flowing through the valve.

The Triode gives rise to Many Inventions

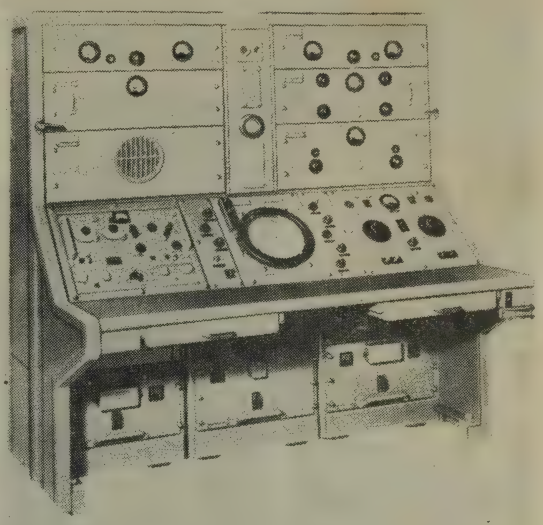
Here was the answer to the problem of making the valve work as an amplifier—and the master key to the subsequent enormous development of the thermionic valve as the heart of all radio apparatus. Lee de Forest called his valve the "Audion"; but it became much more widely known as the "triode," so named because it had **three** electrodes. A truly enormous number of inventions have been developed from the triode—not only innumerable special types of valves with complicated assemblies of up to eight electrodes, but also a wide variety of intricate circuits and apparatus. The fact that the intensity of the electron stream from cathode to anode could be very considerably varied by means of very small variations of grid voltage made it possible to build up, stage by stage, a feeble electrical oscillation into one of enormous amplitude—a magnification of millions to one.

These powerful oscillations could be fed into the aerial of a transmitter; and, furthermore, oscillations corresponding to the much lower frequencies of audible or speech tones could be superimposed on the high-frequency oscillations, a process known as "modulation."

Thus the transmission and reception of the spoken word took the place of the dot and dash signals previously used, and the broadcasting of music naturally followed.

But scores of difficult problems had to be solved. The modern valve is the result of studies of a very fundamental type. The work of the British physicist, W. O. Richardson, on the emission of electrons from hot bodies, deserves special mention, as does the introduction of oxide-coated filaments for which A. Wehnelt was responsible. Later the studies of the versatile scientist, Langmuir, in America, on high vacuum practice, made possible the wonderful techniques by which valves could be manufactured economically in large quantities.

Though the scope of electronic engineering was later to extend far beyond the sphere of radio communications, the next step in its development was also concerned with "communicating"—but this time not a group of sounds, but a picture. First came the transmission of "still" pictures, using a method of scanning systematically each part of the picture in turn, and sending out a series of impulses of varying intensity corresponding to the tone value of the part concerned. Then came television—the transmission of moving pictures, developed very largely by British pioneers. In fact, British scientists and technicians had established a clear leadership up to 1939 when the war put an end to the regular transmissions which were then rapidly becoming an integral part of British entertainment. The technique of television forms a link between radio communications and many other branches of electronics, since it employs a remarkable device called a "cathode ray tube."



Some idea of the complexity of modern radar equipment may be gained from this picture of a complete microwave radar set, with its cathode ray tube and a multiplicity of controls.

The main credit for this invention should be given to the German scientist Karl Ferdinand Braun. The cathode rays, or electron streams, of Crookes and Roentgen (the latter was the discoverer of X-rays) were like an uncontrolled fountain. Braun devised an arrangement of electrodes to produce a narrow "pencil" of rays, and then set about deflecting them by making them pass close to metal plates, contained in the tube, carrying a strong electrostatic charge.

It is worthy of note that as far back as 1896, Sir Ambrose Fleming himself had deflected cathode rays

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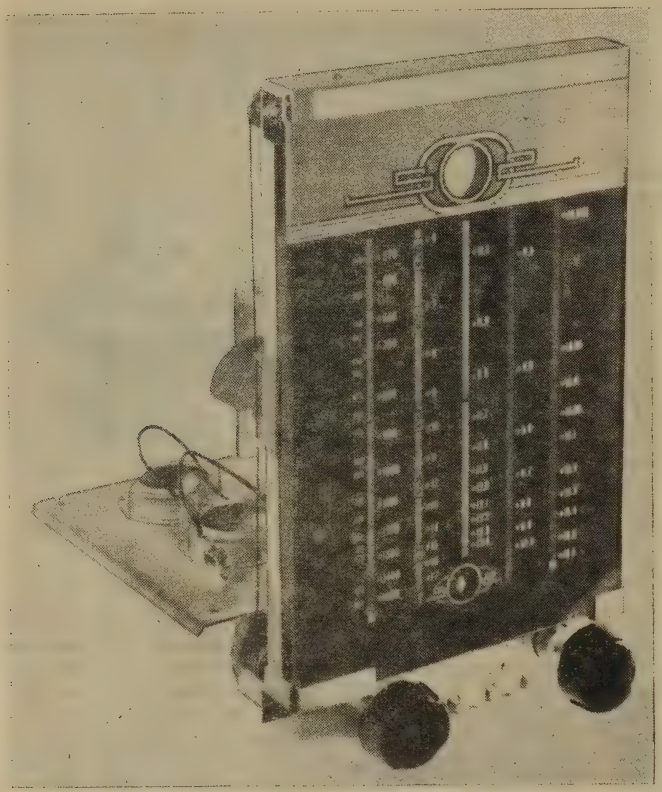

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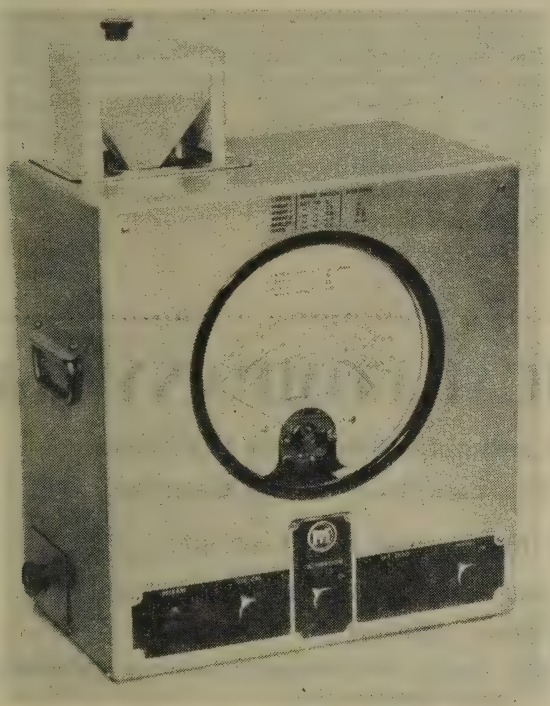
magnetically. Braun went further. By continuously varying the electrostatic charge on his plates, and by using two sets of plates, he was able to vary the direction of the narrow electron beam, in the same way as one would direct a jet of water from a hose. The beam could be made to trace out a pattern as it impinged on the glass wall of the tube; and, by coating the inner surface of that wall with a substance which emits light when bombarded with electrons (a fluorescent substance), the trace would show up very clearly.

This was the forerunner of not only the television tube, brilliantly developed by a number of British scientists, but also of the great range of instruments with which engineers can study the exact form of a mechanical vibration or change occupying less than one-tenth-thousand of a second, doctors can observe



One of the innumerable applications of the electronic method is represented by this simply-operated apparatus which gives a direct and instantaneous reading of the amount of moisture in samples of grain.

in detail the action of the human heart, and specialists in many fields can attack innumerable problems. Moreover, the cathode ray tube is the heart of every one of the great variety of amazing radar devices developed by British engineers.

In 1929 the British Broadcasting Company gave the Scottish television pioneer, John Logie Baird, facilities for experimental transmissions — the first regular moving picture broadcasts in history. The semi-mechanical system then used soon gave place to an all electrical one with much greater definition, for which the "Emitron" camera, one of the most astonishing pieces of apparatus yet devised by the mind of man, was developed. Advances in British television research followed rapidly, and the Alexandra Palace Television Station, which first went into operation in August, 1936, put the B.B.C. well ahead of the rest of the world in vision broadcasting.

British Television Leadership turned to Good Account

It was just when many British manufacturers had begun producing highly efficient televisors at moderate cost that war conditions called a halt to further progress. But these achievements stood Britain in good stead, for many techniques employed were instantly applied to war problems, particularly air defence, with great success. This brings us to a story of a British scientific achievement which perhaps outshines all others of modern times—the invention of radiolocation, now more generally known as radar.

To commence the story of radar it is necessary to go back a few years. One of the great names associated with studies of the "ionosphere"—the layer of electrically charged particles in the upper atmosphere—is that of Sir Edward Appleton, now head of the British Government scientific body, the Department of Scientific and Industrial Research. Advanced researches in the domain of radio had won him a high reputation; but one significant fact may not be generally known. It is that the first experiments in the measurement of the distance of the electrified upper atmosphere were carried out by Appleton in 1924, using a radio rangefinding method. These experiments provided proof of the existence of the Heaviside Layer, so called because it had been theoretically described by Oliver Heaviside, a leading British scientist and mathematician.

Some time afterwards G. Breit and M. A. Tuve, in America, repeated the experiment, using a method which can best be described as a series of pulses, or jabs, of radio energy. In 1931 Appleton simplified the pulse method, and introduced into his experiments the cathode ray tube. The pulses generated were converted into visible traces on the screen of the tube, as also were the reflected ones. Thus he could observe visually the minute interval between the transmitted pulse and the arrival of its reflection, or echo, as a continuously recorded trace.

Since radio waves, like light, travel at 186,000 miles per second, the intervals are naturally very short—only a few millionths of a second. But the ingenious circuit employed makes the rapidly repeated pulses appear as a stationary trace and the repeated echoes appear as another, lagging slightly behind. Thus one of the fundamental principles of radar was known in Britain in 1931!

Between 1921 and 1933 the Superintendent of Radio Research at the Department of Scientific and Industrial Research was a young expert in meteorology and electricity called Robert Watson Watt. The world recognises him to-day as the outstanding genius of radar; and when he was knighted in 1942 it was said of him that he shared the honours with the R.A.F. in winning the Battle of Britain.

As far back as 1919 Watson Watt began to take out a series of patents on direction finding by radio; and in 1935, with L. H. Bainbridge-Bell, E. G. Bowen and A. F. Wilkins, he took up his major researches in aircraft location by radio reflection. This early work culminated in the British Government placing in the hands of a British firm the further develop-

ment and production of an "early warning" system for the detection of approaching aircraft. The success of this early work can be gauged from the fact that by the time the Germans marched into Prague at Easter, 1939, a twenty-four-hour radar watch over the North Sea had been established.

The huge scientific and technical effort which then followed, involving remarkable individual achievements by scores of brilliant men, and the co-ordination of all this work into highly organised systems is much too large a subject for even the briefest mention here. In a speech made on August 14, 1945, Sir Stafford Cripps, Chairman of the Radio Board from 1942 to 1945, duly credited many of the eminent contributors and told a fascinating story.

When it is realised that there are no less than twenty-eight distinct British radar systems, each requiring a volume for its adequate description, and that all this development was accomplished within the short space of ten years, there can be little doubt of the character and capacity of British science. With each new application of radar an entirely new range of components was demanded. A quarter-of-a-million skilled workers were employed. The scale of Britain's war-time electronics industry can be gauged by the fact that, in 1944, thirty-eight million valves, in six hundred different types, were manufactured to supply its needs.

Equally rapid strides have been made in other electronic applications. Almost every important branch of British industry to-day involves at one or more stages of manufacture some electronic apparatus. The chemist is able to observe critical reactions by the swing of a needle or the movement of a dial. The instantaneous determination of the amount of moisture in grain, an accurate test of damp in cotton, minute changes in strain of structures, the acidity of a solution and the immediate detection by "supersonic" sound of flaws in solid metal or other substances are but a few of the hundreds of electronic methods available.

One very important industrial process depends entirely on the thermionic valve. This is the method of developing precisely controlled and highly localised heat conditions in a piece of work by means of high frequency oscillations. "H.F. heating," which has been in use by one British firm for sixteen years, enables a great many stages in the engineering and plastics industries to be carried out which would otherwise be impossible, or at least impractical.

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Its current drain from the 90-volt "B" battery is only 10 to 12 ma. according to the output tube used, and the output power is rated at 0.2 to 0.27 watt, also according to the output tube employed. This power output, though in no way comparable with that obtained from A.C. operated amplifiers, is ample to give room volume from a small speaker, and as long as it is worked within its capabilities it will give excellent reproduction.

COMPONENT LIST

(a) For 1C5 Output Stage:

R_1 = 1 meg. pot.
R_2 = 10 meg.
R_3 = 250k.
R_4 = 0.5 meg.
R_5 = 800 ohms.
R_6 = 25k. pot.
C_1, C_4 = 0.1 mfd.
C_2 = 0.05 mfd.
C_3 = 0.0001 mfd.
C_5 = 25 mfd. 25v. Electro.
C_6 = 0.01 mfd.
V_1 = 1H5-GT.
V_2 = 1C5-G or GT.
T_1 = 9000 ohms — V.C.

(b) For 1Q5-GT Output Stage:

All values the same except for—
V_2 = 1Q5-GT.
T_1 = 8000 ohms — V.C.
R_5 = 400 ohms.

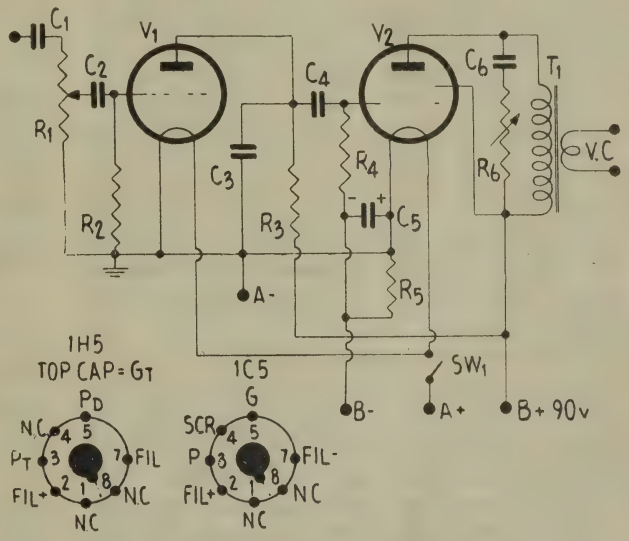
ALTERNATIVE OUTPUT TUBES

One of the difficulties facing constructors at the present time is that of obtaining specified components, and in particular, certain valve types. In the first instance, this amplifier was designed to use a 1C5 in the output stage, but in some localities this tube may not be as readily available as the 1Q5. Both these tubes are 1.4 volt battery types, and may be used in the same basic circuit. For the two types certain circuit values need to be altered, so that we have given two component lists, one for the amplifier using a 1C5, and the other showing the component values which need to be altered to suit the 1Q5, should it be used instead.

THE CIRCUIT

V_1 is the triode section of a 1H5-GT, used as a resistance coupled voltage amplifier. This tube is intended for zero bias operation, which accounts for the rather odd-looking input circuit. In order to operate the 1H5 with zero bias, a very high value of grid-leak resistor, R_2, is necessary. This is 10 megohms in the present case, and since this high value is necessary at all times, it is impossible to use a volume control directly in the position of R_2. Thus, volume control is achieved by making R_1 a 1 meg. potentiometer and resistance capacity coupling the moving arm to the grid of V_1 by means of C_2 and R_2. In this way the grid circuit retains its high D.C. resistance of 10 megohms, while R_1 gives control of the signal input voltage.

The output tube obtains its grid bias voltage by the back-biassing method. Here, B — is con-



nected not to the chassis, but to R_5, the other end of which goes to the chassis. This connection causes the plate current of both tubes to flow through R_5 in such a direction as to make the unearthed end negative with respect to the chassis. R_5 is bypassed by C_5, which is a 25 mfd. electrolytic condenser, and the grid resistor R_4 of the output tube is connected to the negative end of R_5. Thus, a negative grid bias is applied to the grid of V_2 and proper operation is secured.

The A — battery connection is taken directly to the chassis, and A + goes to the filaments through a single-pole switch. There is no need to switch the B + lead, as when the filaments are turned off, the tubes cannot draw plate current, and will not discharge the "B" battery. On account of the biassing method already described, no "C" battery is necessary.

Back biassing also has a further advantage in that the bias on the output tube regulates itself as the battery becomes older, so that the best possible balance between plate voltage and grid bias is preserved. This makes it possible to use a "B" battery down to lower voltages than can be done when fixed bias is used on the output stage. When the "B" battery has run down a little, the fixed bias, if this is used, is too high for the best quality to be obtained, so that either the "B" battery must be discarded earlier than is absolutely necessary, or else the bias must be adjusted as the "B" battery runs down. The present scheme obviates this necessity.

Negative feedback has not been used in this amplifier, since a triode voltage amplifier stage is unsuitable when the simpler forms of negative feedback are introduced into the amplifier. For this reason, control of high frequency response has been incorporated by the well-known shunt-resistance-capacity method. R_6 is therefore the tone control. The small condenser C_3 from the plate of V_1 to earth, helps to prevent high frequency instability without noticeably impairing the reproduction of the high notes.

CONSTRUCTION

The amplifier may be very simply constructed on a small steel or aluminium chassis no bigger than 2 in. x 3 in. x 6 in. The layout is unimportant, and may be left to the individual constructor to decide. The lead to the grid of V_1 should be shielded, since the 1H5 has its grid connection to the top-cap. The leads connecting the components in the input circuit should be as short as possible, and the only wiring precaution which need be taken, apart from this, is that the output wiring should not be close to the input circuit. If this is not taken care of, the amplifier may oscillate, but no difficulty should be experienced, if the circuit is laid out in the normal manner. Battery leads may be taken through a rubber grommet, and the speaker connected by means of a four-pin plug. Only two of the pins will be needed, however, for the speaker must necessarily be of the permanent magnet variety.

OPERATION

Input for the amplifier may be obtained either from a gramophone pick-up or from any suitable radio tuner. If it is intended to work the amplifier from a receiver which already incorporates an audio stage, it might be as well to take the receiver output straight from the detector, if the set is a "straight" or regenerative one, or from the 2nd detector if the receiver is a superhet. The input condenser C_1 should be eliminated or short-circuited where a pick-up is to be used, but should remain in circuit when a tuner is employed, since any detector (including the diode) has a D.C. output voltage as well as the signal. Needless to say, the condenser is then necessary to prevent a direct current being drawn by the 1 meg. volume control.

In using an amplifier of this sort, care must be taken not to overload it if the best quality is desired from it. No one should, but some do, expect an amplifier like this to make as much noise as an A.C. receiver with an output capability of three watts or so. For the best results, the volume level should be noticeably below the point where the ear can detect the distortion. However, if the power limitations are held in mind, and too much in the way of volume is not expected, this amplifier will undoubtedly give very satisfactory results out of a small dynamic speaker.

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TUBE DATA

TYPE EL33 POWER PENTODE

The EL33 and EL3 are identical except for basing. The former has a standard octal base, while the latter uses a side-contact base. The dimensions, electrode arrangement, and under-socket connections of the EL33 are given in Fig. 1.

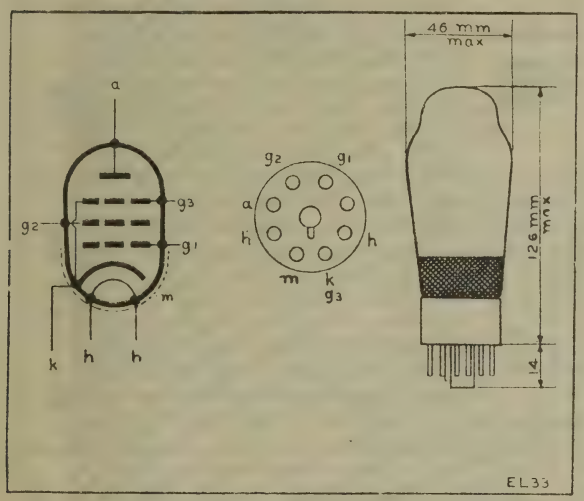

Fig. 1.

General:

The EL33 is a 6-volt heater-cathode type power pentode designed for use in the output stage of receivers and amplifiers, and has a rated power output of 4½ watts with 250 volts on plate and screen.

High Mutual Conductance:

This tube has the unusually high mutual conductance of 9 ma./v., which gives it the advantages of high power sensitivity and high plate efficiency. However, because of the high sensitivity, care must be exercised in its use in order to avoid oscillation at super-audible frequencies, and in push-pull amplifiers to obtain balanced operation. In push-pull operation, tubes matched as to mutual conductance and plate current under identical conditions should be used if the advantages of the push-pull circuit are to be fully realised.

Power Sensitivity:

This is such that a single EL33 with 250v. on plate and screen requires only 0.33v. R.M.S. on the grid for 50 milliwatts output, and 4.2v. R.M.S. for the full output of 4½ watts. It is therefore possible, if desired, to dispense with one stage of audio amplification, and in a super-heterodyne receiver with a diode second detector to excite the output stage directly from the diode load resistor. Alternatively, advantage can be taken of the tube's high mutual conductance by retaining the preceding audio stage and using very heavy negative feedback. The latter, through being greater than normally used, confers greater advantages than usual in the way of reducing distortion and improving the loudspeaker damping, but, at the same time, reasonably high power sensitivity is still obtained.

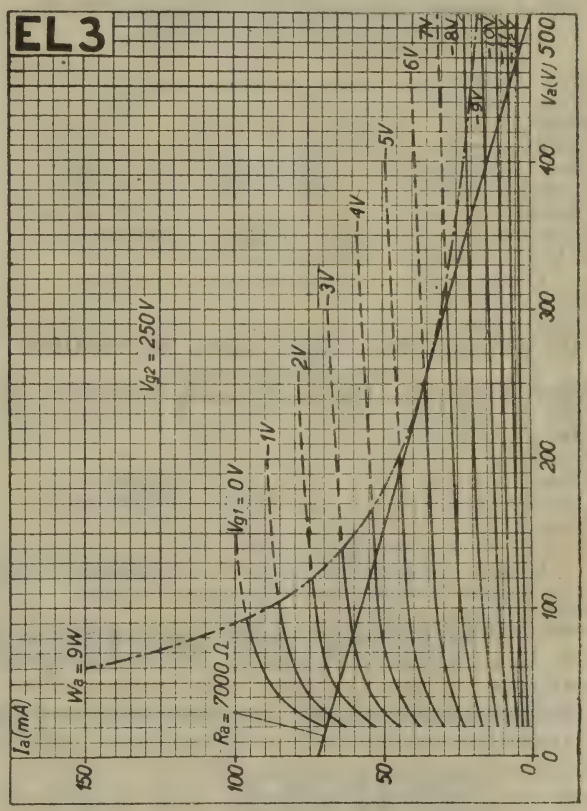

Fig. 2.
Plate characteristics of the EL33. Also shown is the line dividing the permissible operating area from the region where the maximum plate dissipation of 9 watts is exceeded. In addition, there is the load-line for a plate load impedance of 7000 ohms.

Plate Efficiency:

Under normal operating conditions (quoted here), the plate efficiency of the EL33 is 45

ELECTRICAL DATA

(1) HEATER: Indirect heating A.C. or D.C.	
Heater Voltage	6.3v.
Heater Current	0.2 amps.
(2) CAPACITIES	
Grid-plate Capacity	0.8 mmfd.
(3) OPERATING CONDITIONS AS PENTODE	
Plate Voltage	250v.
Screen Voltage	250v.
Plate Current	36 ma.
Grid Voltage	—6v.
Screen Current	4 ma.
Mutual Conductance	9 ma./v.
Plate Load Impedance	7,000 ohms.
R.M.S. Grid Voltage for 50 mw. Output	0.33v.
R.M.S. Grid Voltage for Maximum Output	4.2v.
Power Output	4.5 watts
Cathode Resistor	150 ohms
(4) OPERATING CONDITIONS AS PUSH-PULL PENTODE STAGE (Values are for both tubes.)	
Plate Voltage	250v.
Screen Voltage	250v.
Plate Current (no signal)	48 ma.
Screen Current (no signal)	5.6 ma.
Plate Current (max. signal)	57 ma.
Screen Current (max. signal)	9.2 ma.
Cathode Resistor	140 ohms.
Plate-plate Load Impedance	10,000 ohms.
R.M.S. Grid-grid Voltage for Full Output	13.4v.
Total Distortion	3.1%
Power Output	8.2 watts
(5) OPERATING CONDITIONS AS TRIODE (Screen and plate tied)	
Plate Voltage	250v.
Grid Voltage	—8.5v.
Mutual Conductance	6.5 ma./v.
Amplification Factor	20
Plate Resistance	3,000 ohms.
Cathode Resistor	425 ohms.
Plate Load Impedance	7,000 ohms.
R.M.S. Grid Voltage for 50 mw. Output	1.1v.
R.M.S. Grid Voltage for Full Output	5.9v.
Power Output at 5% Total Distortion	1.1 watts

per cent.—a very high figure. For comparison purposes, it may be stated that, under similar conditions of plate voltage, one well-known beam-tetrode has an efficiency of 36 per cent., while an equally-popular pentode output tube is only 30 per cent. efficient, and has a lower maximum power output.

Because of its high plate efficiency, the EL33 enables a smaller power transformer to be used for a receiver employing a given number of tubes, thus decreasing receiver cost.

Characteristics:

The accompanying tabulated data and graphs give a very complete picture of the tube's characteristics. Fig. 2 gives the plate current-plate-voltage characteristics of the tube in its normal (pentode) connection. On this graph, the dashed line labelled Wa = 9w. shows the region within which the tube may be operated without exceeding the rated plate dissipation of 9 watts. Operation at such a plate voltage and grid bias that the working point falls inside the area where the curves are dotted is inadvisable, since in this area the rated plate dissipation will be exceeded.

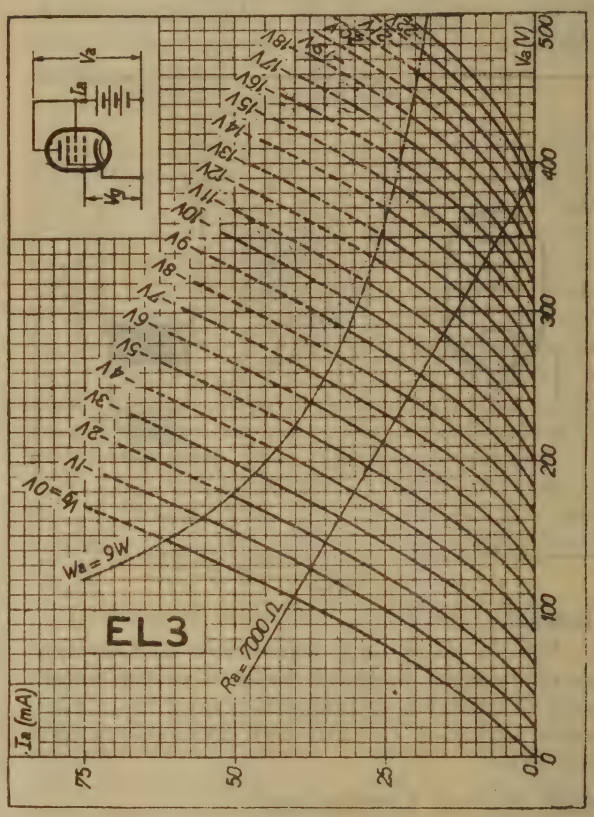

Fig. 3.
Characteristics of the EL33 when connected as a triode, with screen tied to plate.

It is still possible to work the tube with the quiescent point within the permissible area, but for the load to be chosen in such a way that the plate dissipation is exceeded at some portion of the input cycle. The load line for the recommended plate load of 7000 ohms is also shown on Fig. 2, where it can be seen that, with this value of load, and with 250 volts on the plate and —6v. on the grid, neither the operating point nor any points on the load-line fall within the prohibited area. Operating the tube correctly in this manner is more important with a tube like the EL33 than with lower gain tubes.

Fig. 3 gives the plate-current plate-voltage family of curves for the EL33 connected as a triode, with screen tied to plate.

Other Uses of the EL33:

Examination of the tube's characteristics indicate that it should make an excellent R.F. amplifier or frequency multiplier in low-powered transmitter applications. For frequency multiplying in particular, it should prove very useful as long as reasonable precautions are taken.

In using the EL33 in the latter application, care should be taken not to provide too much R.F. grid drive. Since the tube is primarily a Class A audio amplifier, the manufacturers give no data on the maximum permissible grid current, but this may be expected to be very low. This is because of the very small grid-cathode spacing, and because grid emission must be very strictly avoided. However, almost infinitesmal input should be required to drive the EL33 as a "straight" Class C R.F. amplifier, and very little should be needed for frequency multiplying purposes.

When using the EL33 in transmitting circuits, care should be taken also to avoid oscillation.

(*Concluded on page* 48)

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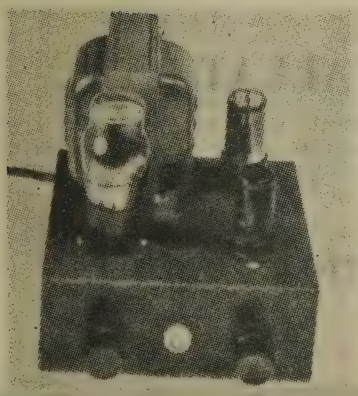

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SERVICE TUBE TESTS—Part I

By the Engineering Division of the Aerovox Corporation

Since the electron tube is the essential part of all radio equipment and very nearly all electronic control apparatus, field tests which purpose to show the condition of tubes have great practical value. Tube tests made as a part of service or maintenance routine, while based upon the same principles as laboratory checks, usually are made in a somewhat different manner, and the data interpreted by simplified methods. This article will describe the methods and circuits employed for service tube testing.

FIELD AND LABORATORY TESTS COMPARED

Vacuum-tube bridges are employed in the laboratory for measurement of three important parameters of grid-controlled vacuum tubes, namely: amplification factor (**s**), plate resistance (rp), and transconductance (Gm). The latter characteristic may be taken with reference to various pairs of electrodes, but generally is assumed to mean **control grid-plate transconductance.** Diode and rectifier characteristics are checked by measuring the plate current (Ip) resulting from application of plate voltage of some specified value.

Quick appraisals of tube characteristics in the field do not permit time-consuming bridge measurements nor the calculations which must follow bridge readings. Commercially available service tube testers check either emission or transconductance of grid-type tubes, plate current of rectifier and diode types, and inter-electrode short circuits in all types. In some testers, transconductance is checked on all grid-type tubes except class-B amplifiers which are tested for power output. For quick appraisal of tube condition, the indicating meters in **all** service tube testers have "English" scales. That is, they are graduated BAD-FAIR-GOOD or REPLACE-?-GOOD.

TYPES OF TESTS

Some controversy has arisen among the designers and users of service tube testers as to which **single** test serves best to indicate the condition of a tube. There seems to be little or no disagreement as regards rectifier, diode, and class-B tubes. Tests made on regular grid-type tubes are the ones raising the question. And those in present widest use include (1) emission, (2) static transconductance, and (3) dynamic transconductance. Of these, the emission test is the simplest and requires the least complicated circuit. It accordingly is frequently found in service tube testers. The following comparison of the three prevailing types of test will serve to establish their differences and relative merits.

Emission Test:

As its name implies, this test attempts to appraise tube condition in terms of the cathode to emit electrons. The test is made by measuring the rectified current flow when a potential of 40 to 50 volts RMS is applied between the tube cathode and all of the other electrodes. The tube filament or heater is operated at its rated voltage. In this way (see Fig. 1) the tube being tested is operated as a diode rectifier, all of its elements except the cathode being connected in parallel to form a multiple plate.

To enable the D.C. milliammeter to cover the wide range of current values encountered with the numerous receiving tubes (0.1 to 100 ma.), a shunt rheostat is connected in parallel with this meter. The rheostat must be set to a specific resistance for each type of tube tested. After the power is switched on, readings may be taken by depressing the push-button switch. The latter serves to protect the milliammeter from over-load while the shunt rheostat is being set.

The emission test cannot be altogether conclusive, since, as tube manufacturers point out, there is no

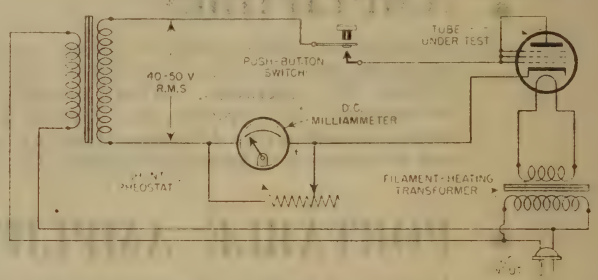

Fig. 1.

Basic circuit for the emission test. Not shown is the switching arrangement for testing various tube types.

definite 100 per cent. emission point which may be used for reference. Also high emission does not necessarily indicate a good tube, since this condition might be present, for instance, in a tube with a faulty grid structure or with a highly emissive spot on its cathode. Very high emission has been observed just before complete tube failure. Nor does fairly low emission necessarily indicate in all cases that the tube is near its end-of-life point. A further disadvantage of the emission test is the liberation of gas within the tube by application of the A.C. test voltage. Unless the test is operated with its recommended D.C. electrode voltages in the emission test, it is not tested under actual operating conditions.

Calibration of privately-built emission testers presents a problem. There is no simple way to calibrate the shunt rheostat in an emission tester. This is because there are no data available on emission values to be expected for the various types of tubes. The most satisfactory method of obtaining a calibration for a specific type of tube consists of adjusting the shunt rheostat with a bad tube of that type in the tester. This tube must have **just** reached the poor performance stage, as indicated by a transconductance type of tester, but must not be burned out. The push button is depressed and the rheostat adjusted for exact centre-scale deflection of the milliammeter (this point on the meter scale should be the top of the BAD or REPLACE region). The rheostat setting then is recorded for that particular tube type.

The emission tester accepts or rejects tubes on the basis of readings obtained along this English scale. In all service testers, the entire left-hand half of the scale is marked BAD or REPLACE, and the entire right-hand half GOOD. The question mark (?), indicating questionable tubes, marks a **line** at

centre scale.

The laboriousness of the "calibration" process and the necessity that a large stock of bad tubes be available for the operation tend to discourage the private construction of emission testers, although the simplicity of the circuit offers a strong initial appeal. The emission tester has the advantage that the same simple circuit is used, without alterations, for checking every type of tube—diodes, triodes, tetrodes, pentodes, converters, dual-purpose types, etc. It is necessary merely to supply a sufficient number of sockets to accommodate the various tube bases.

Static Transconductance Test:

This is commonly called the "grid-shift test." In this test, the grid-type tube is supplied with all of its recommended D.C. electrode voltages, and its filament or heater is operated at rated voltage. A D.C. milliammeter indicates the plate current resulting from application of the D.C. plate voltage. To make the test, the D.C. grid voltage (bias) is increased by

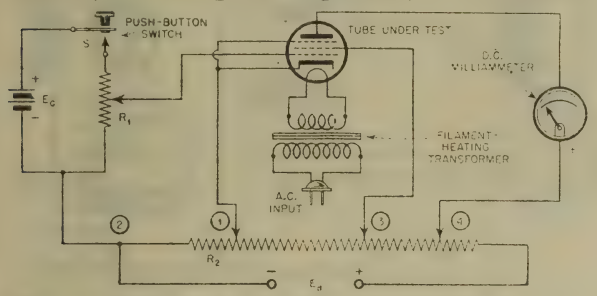

Fig. 2. Basic circuit of the static transconductance test. R_1 is adjusted so that the voltage applied to the control grid when the push-button is depressed is exactly 1 volt. This test is a closer approximation to actual operating conditions than the emission test.

exactly 1 volt in the positive direction, and this causes the plate current to rise to a new value. The transconductance of the tube then may be determined simply by multiplying by 1000 the difference between the two plate current readings. Voltage amplifier and power amplifier tubes are considered defective when their transconductances, as indicated by a test of this sort, fall to 70 per cent. of the values stated in standard tube tables. Oscillator sections of converter tubes are defective when their transconductances fall to 60 per cent. of table values.

When making a static transconductance test, the plate, screen, and suppressor voltages must be checked both before and after shifting the grid voltage. Any voltage change then must be corrected before taking the final plate current reading.

A practical circuit arrangement for static transconductance testing is shown in Fig. 2. E_B is a source of high D.C. voltage, to which is connected the voltage divider resistor, R_2. Sliders along this resistor tap off recommended grid-cathode, screen-cathode, and plate-cathode voltages. The grid-cathode voltage is measured by means of a high-resistance D.C. voltmeter connected between taps 1 and 2, the screen-cathode voltage between 1 and 3, and the plate-cathode voltage between 1 and 4. A single voltmeter may be switched between cathode and the other electrodes, or three separate potentiometers might be provided with calibrated dials. In some laboratory-type transconductance testers where manufacturing cost has not been an important consideration, separate voltmeters are employed for the continuous monitoring of D.C. voltages.

The potentiometer R_1 is adjusted so that exactly 1 volt is obtained from the low-voltage D.C. source, Ec. When the push-button, S, is depressed, the control grid voltage is shifted in value.

For the test, slider 2 is set on the voltage divider resistor for a grid voltage $\frac{1}{2}$ volt lower than recommended bias for the tube under test. When push-button S is depressed, the grid voltage accordingly will be shifted from $\frac{1}{2}$ volt lower than recommended bias to $\frac{1}{2}$ volt higher than this bias. A net shift of 1 volt thus is obtained in the region of recommended bias, without moving too far up the characteristic curve of the tube.

For testing of the wide variety of receiving tubes, the plate milliammeter must have at least three ranges: 0-1, 0-10, and 0-100 ma. D.C.

The static transconductance test has the disadvantage that it often requires that small plate current increments be read on relatively high current scales. This leads to inaccuracy in results. If some means is provided for bucking out the initial plate current through the meter, a lower-range instrument then may be employed to read only plate current change, and may be made to read direct in transconductance (micromhos).

A further, often questioned, disadvantage of the static transconductance test is the fact that the test voltage applied to the control grid is D.C., and in the actual operation of a tube in equipment this is seldom the case, A.C. grid signals being usual. The argument is that here again the tube is not being tested under actual conditions encountered in application.

The static transconductance test is not so widely used at this time. It may be found to-day perhaps only as the "grid-shift" feature of radio set analysers. Occasionally, however, an experimenter who has no tube tester and desires to check a single tube will rig up a grid-shift meter for the purpose.

Dynamic Transconductance Test:

This test, like the previous one, applies recommended D.C. voltages to each tube electrode. These voltages are obtained and checked in the same manner as before. But, unlike the static test, the dynamic transconductance test requires an A.C. grid signal, which more closely approximates tube operating conditions. A 50-cycle voltage from the secondary winding of a step-down transformer is a satisfactory signal.

Practical circuits for dynamic checking of transconductance are shown in Fig. 3. In each case, the plate circuit instrument is an A.C. milliammeter. There accordingly is no deflection of this instrument until an A.C. signal is applied to the control grid of the tube under test.

In Fig. 3-A, the indicating instrument is a dynamometer-type A.C. milliammeter with one coil connected in the tube plate circuit, and the other to a winding of the signal transformer. But since this instrument is rather costly, it never is employed for transconductance testing outside of the laboratory. For service tube tests, the arrangement shown in Fig. 3-B is favoured. Here a standard rectifier-type A.C. milliammeter is connected through a large capacitance, C, (1 mfd. or higher) across a low-resistance, high-impedance choke coil, L. This arrangement is not

as accurate an indicator of A.C. plate current as that of Fig. 3-A, unless the entire combination (meter with capacitor and choke) is calibrated against another A.C. milliammeter and a special scale is drawn.

Upon application of the A.C. grid signal (by depressing push-button S), the plate meter will indicate the resulting A.C. plate current. If the grid signal is exactly 1 volt RMS, the tube transconductance in micromhos will be equal to the meter reading multiplied by 1000. The A.C. milliammeter thus easily may be made a direct-reading micromho meter. The same tube rejection values may be employed as indicated in the description of the static transconductance test.

When an 0-1 A.C. milliammeter is employed and the rejection point is at centre scale, this equation becomes:
(2)

$$Eg = \frac{500}{0.7\ Gm} = \frac{500}{0.7\ (2000)} = 0.357v.$$

In the equations, Eg is the required grid signal (A.C. volts), Ip the desired plate current (A.C. milliamperes), and Gm the rated transconductance (micromhos).

If the oscillator section of a converter tube is being tested, all of the other conditions stated above being taken to be the same, the denominator in Equations (1) and (2) becomes 0.6 Gm.

No elaborate calibration is needed for the dynamic transconductance tester employing an accurate A.C. milliammeter and 1-volt grid-signal, since Gm values are obtained directly from meter readings multiplied mentally by 1000. Calibration procedure for the English scale is simple, it being necessary merely to determine beforehand, by means of Equations (1) or (2), the signal voltage required by each type of tube, and to record that value with the D.C. electrode voltages for the particular type of tube.

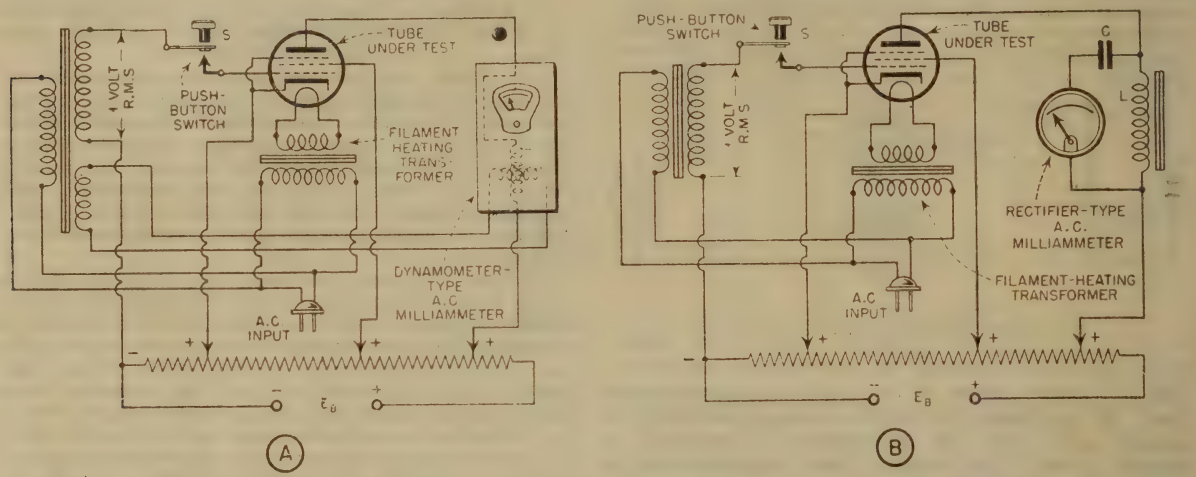

Fig. 3. Fundamental circuits for the dynamic transconductance test. At (a) a dynamometer-type meter is used, which is expensive and necessitates an extra winding on the power transformer. The circuit at B uses an ordinary rectifier-type A.C. milliameter, the D.C. being blocked off by condenser C.

If it is desired to employ the English scale (BAD-?-GOOD), the signal voltage must be made adjustable (for example, through use of a small potentiometer in parallel with the grid-voltage transformer secondary) and must be set for each tube type. These settings must be chosen such that 70 per cent. of a table transconductance value for a certain regular tube, or 60 per cent. of the value for a converter (oscillator section), will be read at the top of the BAD or REPLACE portion of the scale. For example: Let us assume that the plate meter has a range of 0-1 A.C. milliamperes and that a 6C5 type tube is to be tested. The table transconductance value for this tube is 2000 μ mhos. The top of the BAD band on the meter scale will be at about 0.5 ma. It is desired to set the signal voltage to such a value that 70 per cent. of 2000 (or 1400 μ mhos) will be indicated by a $\frac{1}{2}$ milliampere deflection. This required voltage value will be proportional to the required plate current and to the rated transconductance of the tube, and may be determined by means of the equation:
(1)

$$Eg = \frac{1000\ Ip}{0.7\ Gm} = \frac{1000\ (0.5)}{0.7\ (2000)} = 0.357v.$$

(To be continued)

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AN INTRODUCTION TO WIDE-BAND AMPLIFIERS

In Part II of this series we treated in some detail the method known as shunt compensation for extending the high-frequency range of wide-band amplifiers, and gave in detail the procedure to be used in designing a stage using this system.

PART III

OTHER METHODS OF RAISING THE HIGH-FREQUENCY RESPONSE

The shunt-peaking circuit of Fig. 7 is by no means the only one that can be used. There are two other main methods of inductive compensation which are illustrated in Figs. 11 and 11a respectively. The first of these is known as the

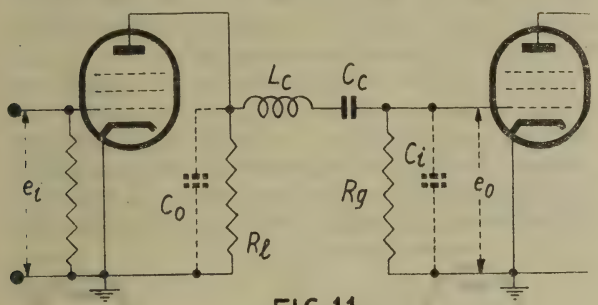


FIG.11

series-peaking or series compensation circuit, and has the advantage of allowing greater gain to be realised than does the shunt circuit. Alternatively, it allows of greater bandwidth, with the same gain as the other circuit.

The series-peaking circuit acts as a filter element, terminated on the one side by Rl and on the other by Rg, and serves effectively to isolate Co from Ci. As a result, the load resistor Rl may be chosen as for the uncompensated stage, but with the important difference that Rl now must equal the reactance of Co at the frequency fo, and not that of Co + Ci. This causes the allowable value of Rl to be higher for a given tube, and therefore a higher gain results.

The design procedure for finding the value of Ll in the series-peaked circuit is quite similar to that for the shunt-peaked circuit. However, space does not permit detailed description of the circuits of Figs. 11 and 11a. The latter is the circuit known as shunt-series peaking, and possesses the advantages of both the series and shunt circuits. Here, again, the possible gain for a given bandwidth is increased by the more complex circuit, and this is used mainly in multi-stage amplifiers, where it is important to reduce the number of stages used, both from the points of view of economy and ease of operation.

If the gain of a shunt-peaked circuit at the frequency fo is called unity, the series and shunt-series circuits have possible gains of 1.5 and 1.8 respectively.

COMPENSATION IN MULTI-STAGE AMPLIFIERS

As can be seen from the foregoing, the question of high-frequency compensation in single amplifier stages is quite readily handled. However, when high voltage or power gain is required, many stages of amplification must be used, and this fact alone brings problems that do not occur in single-stage amplifiers.

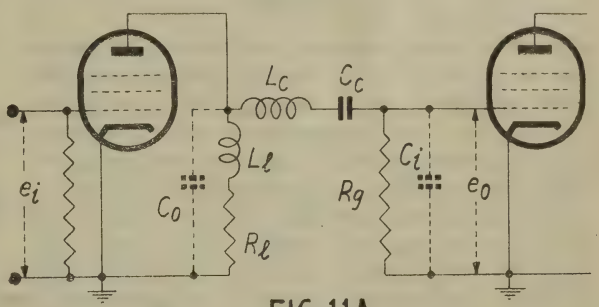


FIG.11A

In Fig. 9 were shown the response curves of single stages using the shunt-peaking method of compensation. Now the curve for the stage where n = 0.5 has only a very slight rise in response between f = 0.3 fo and f = fo, and this stage could be quite satisfactory by itself. However, if it was necessary to have four such stages in cascade, the peak would now have a value of 1.03^4, which is equal to 1.13, and is nearly as high as the peak in the single stage using n = 0.7. A peak as high as this might not be acceptable, as it could cause transient oscillation at the high-frequency end of the band if a sharply-pulsed signal is passed through the amplifier.

Thus, in order to conserve gain in each stage, it may be necessary to accept the high-frequency emphasis obtained, and compensate it by means

of a special stage which has a drop in response corresponding to the rise in the rest of the amplifier.

PHASE RESPONSE

The question of phase response does not normally enter into the consideration of audio amplifiers, but it is important in television and other wide-band amplifiers. Amplitude distortion and phase distortion go hand in hand, for the causes of falling amplitude also bring about a phase shift, whether at high or low frequencies. What this amounts to is that different frequencies take different times to pass through the amplifier. For some purposes, wide-band amplifiers must be made to have zero phase-shift over the whole pass-band, but in general this is not necessary, and as long as the phase-shift is proportional to frequency in the high and low-frequency ranges, the amplifier is considered satisfactory.

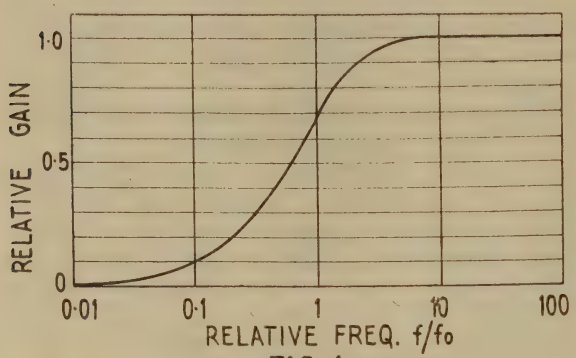


FIG. 6

In wide-band amplifier practice, the term "linear phase response" means that, except for the middle range, where there is zero phase-shift, the phase-shift that does occur is proportional to frequency. The high-frequency compensation circuits given in this article automatically provide this sort of phase characteristic in the region between 0.2fo and fo, the phase-shift being zero up to the lower of these two frequencies.

The significance of the above-defined phase response is that then all frequencies in the pass band take the same time to pass through the amplifier. This is clearly of importance in television work, but in oscillograph amplifiers used for the delineation of waveforms, it should be remembered that the compensating circuits may possibly cause a change in the waveform being examined if the very high frequency components are at all prominent.

LOW-FREQUENCY COMPENSATION

In Fig. 6, reproduced here, was given the generalised low-frequency response curve of an amplifier stage in which the dropping off of response was caused purely by the finite size of the coupling condenser Cc. Here, fo refers to the low frequency at which the response has fallen to 0.707 times the value in the mid-frequency range. Here, again, a simple relationship occurs between the various factors involved, for *fo is the frequency at which the following grid resistor Rg equals the reactance of the coupling condenser Cc.*

It would seem on the surface that there is a very simple remedy to the loss of low-frequency gain, and that is to increase either Rg or Cc, or both. This could be quite true but for the fact that there are practical limits to the size of both these components.

In the first place, there is an upper limit to the size of Rg, imposed by the requirements of the succeeding valve, which must not have more than 0.5 to 1 meg. D.C. resistance between grid and earth if it is to operate properly.

There are, in addition, two factors which set an upper limit to the size of Cc. All paper condensers, such as those normally used for this purpose, have a certain amount of leakage, which is greater the larger the condenser. If the leakage becomes excessive, it tends to neutralise the grid bias of the following tube and causes improper operation. Also, as the capacity of the coupling condenser is increased, so is its physical size, and therefore its stray capacity to earth. Thus, the use of too large a condenser can cause an intolerable increase in Co, the output capacity of the preceding stage, with consequent detrimental effect on the high-frequency performance.

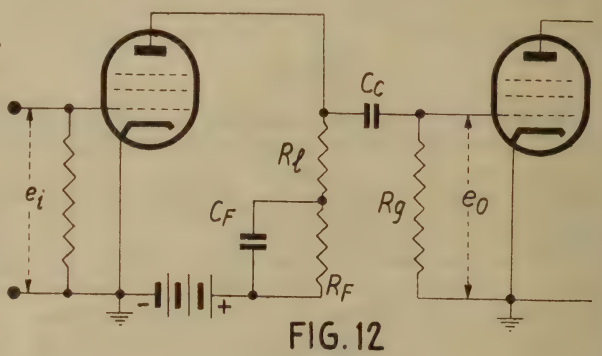


FIG. 12

Thus, it can be seen that the low-frequency response cannot be indefinitely improved simply by increasing the size of the coupling elements. There is a further disadvantage of this scheme, in that very large C.R. products in the interstage couplings of an amplifier tend to increase its liability to motor-boating, or very low frequency oscillation.

All of the foregoing indicates that at the low-frequency end of the range, too, special compensating circuits are necessary if extremely good

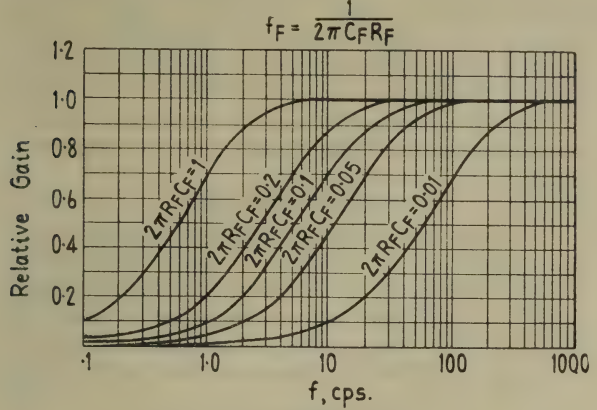


FIG. 13

low-frequency response is required. The question is quite an academic one when audio amplification only is being considered, but, as before, television and oscillograph amplifiers have more stringent requirements. For instance, if an amplifier is to reproduce accurately a square wave of, say, 12.5 c/sec. fundamental frequency, it must not simply have usable gain at this frequency, but must have a response "flat" down to this frequency, which is a very different thing.

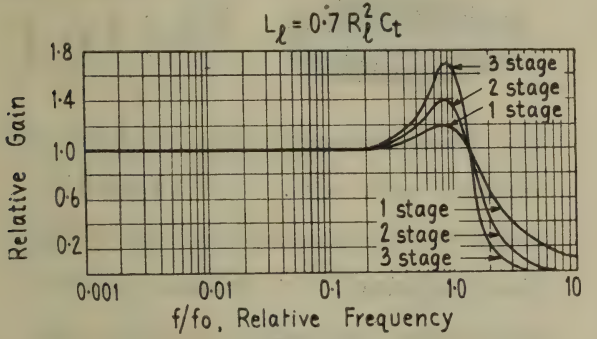


FIG. 14

This shows the effect of cascading over-compensated stages with a high-frequency response as for the curve labelled 1 stage.

LOW-FREQUENCY COMPENSATION

Fig. 12 shows the circuit used in compensating for the loss in low-frequency response caused by the Cc-Rg combination. The additional components of Rf and Cf are connected in the load circuit as shown. It will be noted that the valve capacities have been omitted from this diagram, as they have no effect whatever on the low-frequency operation of the stage. The practical point at issue is, how are the values of Cf and Rf chosen?

It may be proved mathematically that the greatest compensation is obtained by making the product Rf.Cf as great as possible when a given value of Rg.Cc is being used, but that a very useful result is obtained (without carrying the compensation to the point where the series resistance in the plate supply lead is too great) by making the value Rp.Cf equal to the product Rg.Cc where Rp is the value of Rl and Rf in parallel, so that

$$Rp = \frac{Rf.Rl}{Rf + Rl}$$

Thus, Rf is first chosen so that the voltage drop across it does not reduce the available H.T. voltage too much, and Rp is worked out from the above formula. Then the values of Cc and Rg are chosen, from the considerations already outlined, and Cf is found from the relation

$$Cf = \frac{Rg.Cc}{Rp}$$

The type of compensation given by this procedure is illustrated in Fig. 13, where actual cases are shown in which the values of 2πRf.Cf vary from 1.0 to 0.01. This demonstrates very well the increased low-frequency response afforded by the compensating circuit.

OTHER CAUSES OF LOW-FREQUENCY LOSS

In the example of low-frequency compensation given, the only cause of low-frequency loss was the coupling network. However, as with audio amplifiers, insufficiently by-passed cathode and screen resistors can and do have a similar effect. These may be compensated in exactly the same way as can the loss in the coupling network. For example, if Ck and Rk are the cathode resistor and by-pass condenser, then the falling-off due to these components may be offset by introducing a plate filter RfCf such that

$$Rk.Ck = Rf.Cf.$$

The only trouble with this arrangement is that only one plate filter can be used in a particular stage, and this can compensate only for one defect at a time. Thus, in multi-stage amplifiers, it is necessary to compensate for the grid-coupling networks in some stages and the cathode networks in others. This means that it is good policy to use other than cathode bias in some stages in order to remove the necessity for compensating for the cathode impedance.

THE USE OF CATHODE FOLLOWERS

In wide-band amplifiers, considerable use is made of the cathode-follower circuit, whose advantages of high input and low output impedance serve to improve the characteristics of the amplifier at both high and low frequencies.

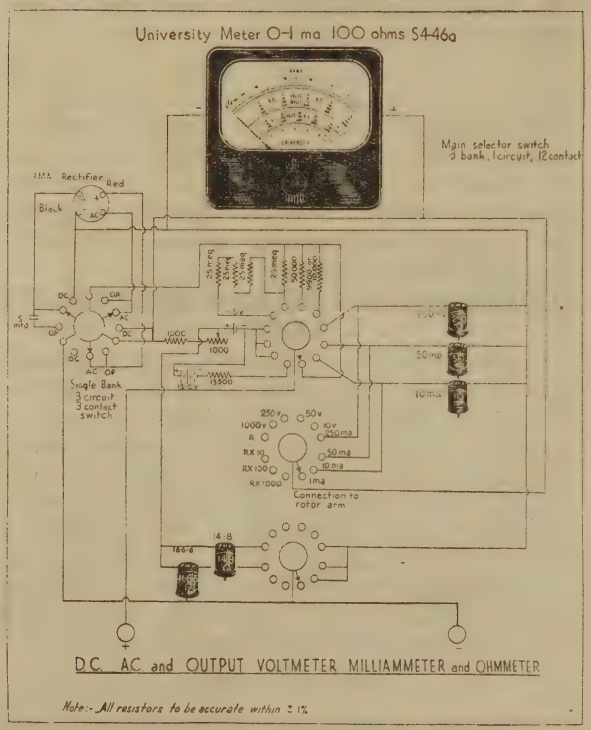
If a cathode follower is used as a buffer between amplifier stages, its very high input impedance increases by a factor of several times the product Rg.Cc, thus improving the low-frequency response. At the same time, the reduced input capacity of the cathode follower decreases the total shunt capacity which has to be compensated, making the high-frequency compensation easier to achieve. Again, the very low output impedance—between one-half and one-tenth of the normal plate load resistor—causes the input capacity Ci of the following stage to be so much less effective in reducing high-frequency response.

Apart from its use as a buffer amplifier, the cathode-follower finds use in wide-band amplifiers as an output stage, for coupling the amplifier to a low-impedance line, such as a coaxial cable. As previously mentioned in these pages, it can also find similar use in audio and oscilloscope circuits, and can replace plate-to-line transformers with excellent effect.

CONCLUSION

The material in this series of articles does not pretend to be exhaustive, either in terms of subject matter or of treatment. It was intended purely to indicate some of the methods used to increase the bandwidth of normal resistance-capacity coupled amplifiers, and to serve as an

(*Continued on page* 48)



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———Radio Saigon, Boite Postal 412, Saigon, Indo-China, Francaise.

GOLD COAST:

ZOY.—P.O. Box 250, Accra, Gold Coast, West Africa.

GUADELOUPE:

FG8AH.—"Radio Guadeloupe," Pointe-a-Pitre, Guadeloupe, F.W.I. (Box 125).

GUATEMALA:

TGOA.—"La Voz de Las Americas," Hotel Palace, 12 Calle y Cuarta, Guatemala City.

TGWA.—"Radio Nacional de Guatemala," Guatemala City.

GREECE:

SVM.—Cable and Wireless, Ltd., P.O. Box 8, Athens.

MEASUREMENT OF FREQUENCY

PART V

MULTIVIBRATOR ACTION

Before going on to describe the adjustment of the 100 kc/sec. multivibrator to its correct frequency, locked to the 100 kc/sec. oscillator, it would perhaps be as well to describe the action of multivibrators in general. Fig. 1 is the circuit of the most commonly used multivibrator, and corresponds almost exactly with the multivibrator circuit given in Part IV of this series. V_1 and V_2 are ordinary medium-mu triodes, and the output of each is resistance capacity coupled to the grid of the other. The circuit is assumed to be symmetrical, so that as well as the tubes, R_1 and R_3, C_1 and C_2 and R_2 and R_4 are identical in value. It seems obvious, on inspection, that such a system should oscillate in some manner, but just how, and at what frequency, is not immediately apparent.

If the symmetry of the circuit were exact, i.e., all resistors, condensers, and the valves in each side of the circuit perfectly matched, it would appear that the circuit would be in equilibrium, and that oscillation would not occur. If this were so, even a small disturbance in plate or grid voltage of one of the tubes could cause one of the tubes to draw more current than the other, and the equilibrium would be upset.

As a starting point, suppose that this upset has just occurred, and that V_1 is now drawing more current than V_2. This increases the voltage drop across R_3, and this drop is impressed on the grid of V_2 via the condenser C_1. This drop in voltage causes V_2 to draw less current, and the voltage at its plate to increase. This, through C_2, causes an increase in the grid voltage of V_1, so that this tube now draws even more current. Thus, by regenerative action, the current in V_1 increases very rapidly, and at the same time the the current in V_2 decreases very rapidly, and even becomes cut off. This action is shown graphically in Fig. 2, in which the wave-form at the top shows the plate-voltage of V_1. The regenerative increase in plate current of V_1 corresponds to one of the rapid falls in plate voltage shown on the diagram. The next lowest wave-form is that of the grid voltage of V_2. Corresponding in time with the drop in plate voltage of V_1 is the equally sudden drop in grid voltage of V_2. On the grid voltage diagram, the voltage levels corresponding to cut-off for the valve and zero grid volts are shown. In the plate diagram, the reference level is the potential of the H.T. line, and Emin is the voltage at the plate when the tube is drawing maximum current.

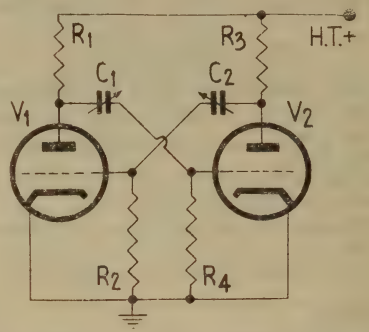

Fig. 1. Multivibrator circuit used in the accompanying description of how the device operates.

On the regenerative increase in plate current already described, the grid of V_2 is driven negatively, far beyond cut off, so that V_2 becomes non-conducting. Thus, at the same time, the plate voltage of V_2 rises to the full H.T. voltage. This can be seen happening at the same time as the other two effects, in the lowest wave-form, which shows the plate voltage of V_2.

To summarise so far, the disturbance of the circuit's equilibrium has caused V_1 to conduct heavily, a high negative voltage to be applied to the grid of V_2, and the latter in consequence to be cut off. Since the condenser C has become negatively charged in taking the grid of V_2 beyond cut-off, this tube will **remain** cut off until the charge has leaked away. Thus, the wave-form Eg_2 in Fig. 2 shows this negative charge leaking away exponentially through R_4, after the initial sudden drop. When the grid voltage of V_2 reaches the cut-off bias of the tube, the latter starts to conduct slightly. This causes a voltage drop to appear across its load resistor R_3. This drop is transferred by C_2 to the grid of V_1, so that its grid voltage falls. The plate current of V_1 therefore falls, and its plate voltage rises. This rise is transferred through C_1 to the grid of V_2, accelerating the change in plate current of this tube. The effect, therefore, takes place cumulatively, and in a very short space of time V_2 becomes heavily conducting and V_1 becomes cut off.

This is exactly the reverse of the situation

described previously. Now, the negative grid voltage of V_1 leaks away until V_1 starts to conduct, and the rapid change-over of plate current occurs again. Thus, the cycle is complete, and carries on indefinitely.

There are two points about Fig. 2 which require elucidation before leaving the action of

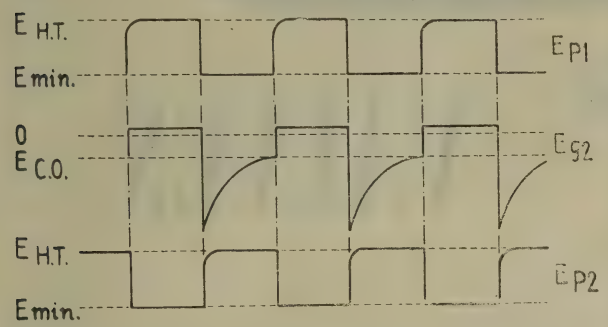

Fig. 2. Wave-forms of the voltage at various points on the circuit of Fig. 1. From top to bottom are Ep_1, the plate wave-form of V_1, Eg_2, the grid wave-form of V_2, and the plate wave-form of V_2 at the bottom. The grid wave-form of V_1 is similar to that of V_2, but displaced sideways along the time axis by half a cycle.

the multivibrator. First, the wave-form labelled Eg_2 shows that the grid goes only a volt or two positive even though the plate voltage swing may be 150 volts or so. The reason for this is that, as soon as either grid is driven positive, grid current flows and limits the positive voltage actually developed at the grid to a very low value, determined by the grid-cathode resistance when grid-current is flowing.

The second point is the somewhat rounded shape of the plate voltage rise in both tubes, compared with the quite straight fall in plate voltage. This is explained as follows: When either valve becomes cut off (which occurs almost instantaneously, owing to the regenerative action) the plate voltage is unable to rise instantaneously on account of the stray capacities associated with the plate circuit. Thus, the slightly rounded rise of plate voltage represents the exponential charging of the stray capacities and the plate-cathode capacity. However, when the fall in plate voltage happens, i.e., when the valve suddenly becomes conducting, the valve forms a low-resistance discharge path for these capacities, which therefore discharge much more quickly than they charge.

FREQUENCY OF OPERATION

The foregoing description has indicated how the multivibrator comes to act as an oscillator, but leaves a number of points unexplained. Chief among these is the question of frequency of operation. The exact frequency is a complicated function of all the circuit constants and voltages, but the main item is the time-constant of the combination C_1R_4, and of course, that of C_2R_2, which is identical with that of the former.

The rapid change-over periods in which one valve becomes cut off and the other becomes conducting are almost instantaneous, and can have very little effect on the frequency. If the second wave-form on Fig. 2 is considered, it is apparent that the factor which determines how long V_2 remains non-conducting is the time taken for the coupling condenser to discharge. This time is determined by the size of the condenser and the size of the resistor R_4 through which it has to discharge. Thus, the greater the CR product of these components, the longer the time taken, and the lower the frequency of operation. Obviously the product of C_2 and R_2 is equally important, as this determines the length of time during which V_1 remains cut off on the other half of the cycle. Thus, in the circuit of the multivibrator given in Part IV of this series, the two coupling condensers are made variable, and may be adjusted simultaneously to give a coarse frequency adjustment. Calculation indicated that about 12.5 mmfd. was required to give 100 kc/sec. with the other values used, so that a 0-30 mmfd. condenser gives plenty of latitude for the adjustment.

LOCKING OF MULTIVIBRATOR

The property of this circuit which makes it so useful for our present purpose is that it is capable, unlike sine-wave oscillators, of being locked in frequency quite rigidly, by injecting some other frequency into the circuit. It is most readily locked by voltages at one of its harmonics, so that in this case, some of the output of the 1000 kc/sec. oscillator (the 10th harmonic of 100 kc/sec.) is fed into the plate circuit of the multivibrator. If now the amplitude of the locking voltage is made variable, we have all that is necessary to lock the multivibrator exactly to 100 kc/sec. provided that the 1000 kc/sec. oscillator is exactly on frequency. In order that the locking process may be carried out most easily, it is necessary to understand something of the mechanism of locking.

As we saw previously, what determines the free-running frequency of the multivibrator is the time taken for the grid which is below cut-off, to reach such a voltage that the plate of the same

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tube starts to draw current again. If by some outside means, we artificially cause the tube to become conducting, slightly **before** it would otherwise have done, then the rapid change-over will occur **earlier** than it would have done.

If then we initiate the change-over a trifle early, and at a pre-determined rate, this rate will fix the frequency of the multivibrator and not the circuit constants alone. The "outside means" referred to could be, for example, a series of positive pulses applied to the multivibrator grids. If the pulses occur at a rate slightly faster than the free-running rate of the multivibrator, then the latter will become "locked" in frequency to the frequency of the pulses.

Pulses are not necessary in order to lock the multivibrator. Any wave-form of the desired frequency, fed into the circuit in the appropriate manner, can cause locking. In the circuit given in the last instalment, V_1 is the synchronising tube. It has a small plate load resistor of 2000 ohms, across which is developed a voltage at 1000 kc/sec. derived from the 1000 kc/sec. oscil-

AN IMPORTANT CORRECTION

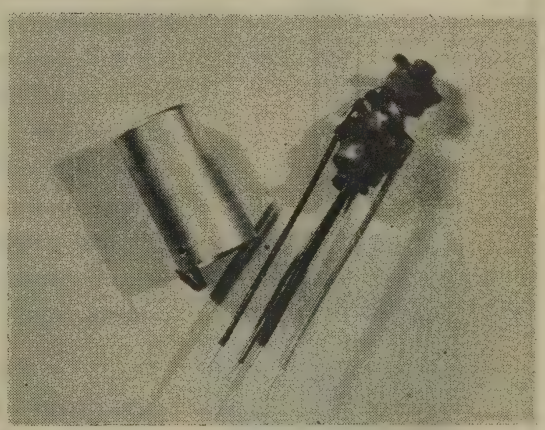
In the last issue of *Radio and Electronics* (December, 1946) there was rather a serious error in the circuit of the "High Quality Broadcast Tuner" described on page 6. As drawn, the 50k. grid resistor of the 6K8 oscillator section is in parallel with the grid condenser. Instead, it should go from the oscillator grid to the 6K8 cathode, for as drawn, there is no D.C. grid return for the oscillator section, which in consequence would not work at all if connected in this way. We should be very grateful to readers who may know of anyone having trouble on account of this error, if they would draw attention to this correction, which will set matters right.

THE EDITORS

MIDGET I.F. TRANSFORMERS

The new midget I.F. transformers developed by Hohner are by far the smallest manufactured in New Zealand. They measure only 2 in. long by 1⅛ in., and although they are small, the Q is excellent—in fact, very little difference can be found when compared with a standard transformer. The transformers are permeability tuned, and the coils are wound on polystyrene former.

The Hohner midget I.F. transformers are admirably suited for portable and small radios.



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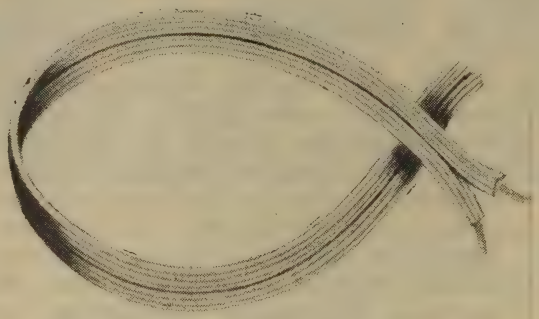

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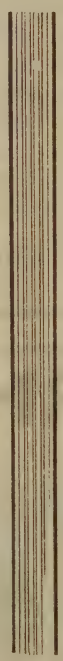

A new paralleled cord with qualities never available in similarly constructed rubber types—because this type of insulation has high dielectric strength, high abrasion resistance, high impact resistance, and practically ageless insulation. It also exhibits inertness and resistance to the deteriorating effects of oil, water, alcohol, acids, alkalies and most common solvents and has no chemical reaction between copper conductor and insulation.

Although this plastic insulation is "rubber like" it excels rubber compounds in many respects. Its breakdown voltage for instance is 20,000 volts, as compared to 10,000 volts breakdown on rubber insulation.

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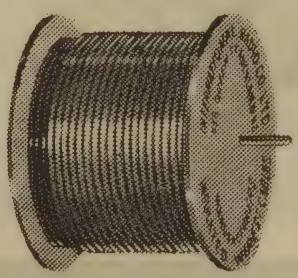

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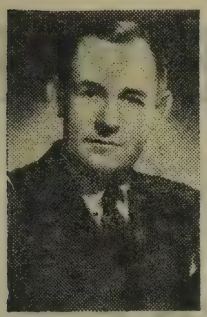

Mr. H. R. HALLIDAY

International Radio may well be proud of their new Australian Manager and Technical Director, Mr. H. R. Halliday. His professional engineering qualifications and experience in the manufacture, research and installation of cables, place him among the top-rankers in the field.

We hope that Mr. Halliday will visit New Zealand in the near future, and if so, we look forward to making his acquaintance.

Bernie Giles and Ken Elliott, to whom we have referred in our Trade Winds as introducing Photo Finish Equipment to New Zealand, are old identities in radio. Bernie, it will be remembered, was with Thomas Ballingers, Fears, and Collier and Beale of Wellington. Prior to the outbreak of war he was called up, and almost immediately became Assistant Staff Officer, Naval Operations. Bernie then saw service in England, being engaged on radar and communications. His next appointment was to Washington, where he was Naval representative on the Joint Chiefs of Staff and represented the three Services on the Combined Communications Board. During this time he was promoted to the rank of Commander.

Ken Elliott—the other half of the firm—also saw service in the Navy, and for the initial two years he was occupied with the development and trials of naval radar. Throughout the war, Ken served on many ships in almost every theatre of war, and during the latter part was on submarines.

Between Photo Finishes, Bernie and Ken are distributors, wholesalers and importers of radio and electrical equipment.

* * *

Keith Alexander of Swan Electric is at the moment "on tour" for his company, and will be travelling as far north as Gisborne.

* * *

Charlie Roser, Advertising and Radio Manager of National Electric, is a frequent visitor to our office these days. His cheery smile, useful suggestions and valve data books have and always will be very welcome.

* * *

Fred Richardson of Bradley's Electrical Co. was married in Christchurch on 16th November. We wish Mr. and Mrs. Richardson all the very best for the future.

* * *

Bernie Rundle, Managing Director of Western Electric, and Phil Mason, Operating Manager, have been on a complete tour of the South Island, making a general check-up on Western Electric equipped theatres in the South.

* * *

Among the many radio men to get back to civilian occupations during the year is Matt Johnston of Matt Johnston Ltd., Timaru. After service in the R.N.Z.A.F., and later as wireless operator-technician in the Merchant Navy, Matt is again back in business, and well settled down. Months of organising has had its moments, but with a congenial team—six at the moment—all problems have been overcome. A former "Ham" before the war, Matt has lost none of his former enthusiasm.

* * *

We heard that Norm Swann travelled South a week or so ago, and we quite naturally assumed it was a business trip. Later, however, we discovered that Norm and "Horry" Olsen are part owners in a horse which enjoys the name of "Technique." It was obvious then that Norm went to Christchurch to see the gee-gee win. Unfortunately, we regret to inform our readers that the noble animal let Norm and Horry down. Our advice is that you had better find a new "technique," Norm.

* * *

A few months ago we recorded in these columns the fact that Alan Clarke of International Radio was a little irked about our fair city's climate. We think Alan took our remarks seriously, for he called a few days ago wearing a woollen pullover, heavy overcoat, woollen scarf, and a sinister smile—and this, mark you, at the end of November!

* * *

For many years one of the biggest sporting and social events in the radio industry has been the annual football match between Radio Ltd., of Auckland, and Akrad Radio Corp., of Waihi. This year, the match had its surprises! Though in the past Akrad have won every game, Radio Ltd. determined they had stood enough of this nonsense and won the day by 40 points to nil.

The match was played at Waihi where the visitors spent the night, finishing the evening with a sample of Akrad's hospitality. We understand that Akrad really spread themselves, or rather the tables, in a manner reminiscent of pre-war days. The social and dance was a successful culmination to an annual event which is something to which both Radio Ltd. and Akrad look forward with eager anticipation every year.

The organising efforts of "Mac" Hamilton of Radio Ltd., and Dick Murry of Akrad were a large contributing factor to the success of the day.

PUBLICATIONS RECEIVED

Electronics in Industry

This well-illustrated brochure published by the British-Thomson-Houston Co., Ltd., serves as an excellent introduction to the applications of electronics to a great variety of industrial problems and processes. The advantages of electronic control are outlined; there is an excellent page on industrial valve terminology, and a chart which outlines some of the industries and purposes for which electronic equipment is actually working. The bulk of the 24 pages is concerned with illustrated descriptions of equipment used for photo-electric control, temperature measurement and control, electronic timing equipment, thyratron motor control, electronic voltage regulation, electronic speed control, and radio frequency heating to mention only some of the topics dealt with.

Copies of this useful and instructive publication may be obtained on application to Messrs. National Electrical and Engineering Co., Ltd., Wellington.

(Continued on page 47)

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Mutual conductance 2 mA/V.
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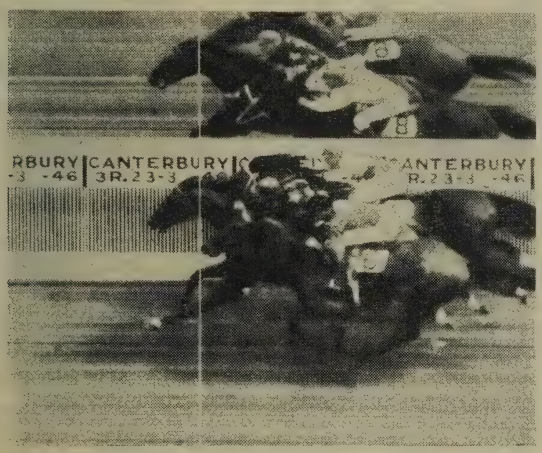
TRADE WINDS

Giles and Elliott Introduce Photo Finish Equipment

There has always been an extremely interesting aspect to Photo Finish equipment which has now been introduced into New Zealand and Australia by Messrs. Giles and Elliott of Wellington. Photo Finish has been advocated for many years, and the above firm has obtained and installed equipment which measures up to the exacting standards required by Racing Clubs. Already, the apparatus has been installed at Ellerslie and Addington, whilst other Racing Clubs are following suit.



In addition, Messrs. Giles and Elliott have introduced the equipment into Australia and are now associated with the company operating there.

It is significant that, since the equipment has been installed, the judges have called for Photo-finish results on an average of three to four times each race day. In fact, the second and third places in the last Melbourne Cup were Photo-finishes.

The operation of this equipment is most interesting, the unique point being that the camera has neither shutter nor diaphragm—nor is it a movie camera. A movie camera could not be used as there is a possibility of the horse passing the winning post during the time taken by the film to move from each frame. Photo-finish can give an accuracy to one eight-hundredth of a second.

The apparatus photographs through a narrow slit which exposes about three inches of the winning post. The film moves behind the slit, and is synchronised to move at the same speed as that at which the horses would pass the post. On the other side of the track, and in view of the camera, is a spinning drum on which is marked a series of timing lines. The rotation of the drum is also synchronised with the film, and on the completed picture the lines of the spinning drum indicate the time interval between the first and remaining horses. In actual fact, each horse is photographed as it passes the winning post.

Mounted above the spinning drum is a stationary mirror, the purpose of which is to give the judges an uninterrupted and simultaneous view of the horses from each side of the track.

The illustration shows the stroboscopic effect of the photo-finish—the railings seen on the far side of the track are individual lines photographed in synchronism with the moving film; only one rail is actually visible at any one time. The upper portion of the photograph shows the reflected image from the other side of the track.

* * *

Modern Production Methods

Visitors to Swan Electric Company's factory cannot but help being most impressed by the ingenious and modern methods used in the production of Rola Speakers.

Perhaps the most outstanding process is the manufacture of the speaker cones. The paper pulp is imported, and after being specially prepared, is moulded, pressed and dried in a chain of most interesting processes. This in itself is no mean feat, as the cone must be mechanically rigid and accurate to comply with the close tolerances necessary in speaker manufacture. The many parts comprising a speaker are made in the factory, and, while some are normal routine operations, others involve completely new ideas. The voice coil former is made from special bakelised paper to eliminate mechanical distortion, and the spider is pressed and heat treated bakelised linen. The type of construction allows easy movement of the voice coil, but at the same time maintains an accurate alignment within the narrow gap of the field.

All components after manufacture are assembled on jigs and are passed through infra-red lamp ovens to complete the drying of the cement.

The many other departments, such as transformer and field coil winding, magnetising of P.M. speakers, and finishing department, combine to make Swan Electric one of the busiest factories in the industry.

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A Practical Beginners' Course

PART 6.

The next circuit to be tried is very simple and requires no further building. It is shown in Fig. 6. Here, the aerial is connected to the top of the tuning coil, but not directly, because the fixed condenser C_1 is placed in the aerial lead. In order to try this circuit, there is no need to take the aerial coil off the former and undo all the effort expended in making it. It is enough simply to disconnect the aerial coil by unsoldering the lead from the lower end which went to the earth connection. The tappings are left unconnected by removing the "alligator clip." The aerial coil is now entirely out of the circuit, and will have no effect on the operation of the set.

SIZES OF CONDENSER

For the experiment with a condenser in the aerial lead, you will need a number of fixed condensers of different sizes. Apart from their use in the experiment, they will come in handy for use in other circuits later. The necessary sizes are one each of 0.00005μf., 0.0001μf., 0.00025μ., and 0.0005μf. They will be of the small variety about the size of a postage stamp, and are quite inexpensive. **Mica** condensers should be asked for, as this is the insulating material normally used in small sized condensers of this type.

First of all, the set is tuned to a station with the aerial connected directly to the top of the tuned circuit, and the point on the dial for greatest signal strength is noted. Next, the 0.0005 mmfd. condenser is connected between the aerial and the top of the tuned circuit. This is done without disturbing the setting of the cat's whisker, and the set is re-tuned to the same station. The new dial position for greatest signal strength is noted, as is also the amount of shift from the previous position. Now the procedure is repeated, using the 0.00025 mmfd. condenser instead of the 0.0005 mmfd. one, and the difference between the dial settings for these two condensers is noted. The same performance is then gone through with the other two condensers, and the results are noted in the same way as before.

When this experiment has been completed, compare the results with the ones you obtained in the similar experiment using the tappings on the aerial coil. If both have been properly performed, the results should be very similar, and this fact serves as an introduction to the important subject of **coupling** between circuits.

COUPLING

We have met this term before in connection with the aerial coil, which was said to be **coupled** to the tuned circuit coil. It will be remembered that the coupling was said to be **loose** if the aerial coil was not very close to the other coil, or **tight** if the two coils were close together. Now, the purpose of the aerial coil is to couple the aerial to the tuned circuit, and to enable radio currents in the aerial to be transferred in a desirable manner to the tuned circuit. In the experiment we have just performed using aerial condensers instead of a coil, the purpose of the condenser is exactly the same as that of the coil. We have, therefore, two separate methods of coupling the aerial to the tuned circuit. These methods are called **inductive** and **capacitative** coupling. It is not difficult to see why, if we remember that the electrical property of a coil is called **inductance** and that of a condenser **capacity**.

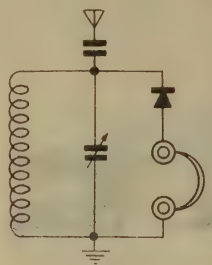


FIG. 6

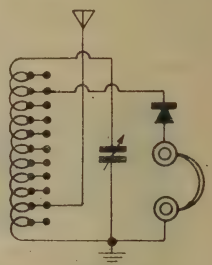


FIG. 7

Inductive coupling, therefore, means "coupling by means of inductance," and capacitative coupling means "coupling by means of capacity."

Capacitative coupling is really simpler than inductive coupling because (if we consider the circuit of Fig. 6) the size or capacity of the aerial-coupling condenser is the only thing which can affect the way in which the circuit works.

INDUCTIVE COUPLING

When we have inductive coupling between the aerial and the tuned circuit, there are two factors which determine the final effect. Firstly, there is the size or inductance of the coupling coil, and secondly there is the distance between the coupling coil and the tuned circuit's coil. With inductive coupling a very complicated series of effects can take place if the size of the aerial coil and its distance from the tuned circuit are varied simultaneously.

It was for this reason that in our experiment we wound a fixed aerial coil and tried altering only its size. However, had we used a movable aerial coil and kept its number of turns fixed, we would have found that, with the tightest (or closest) coupling between the two coils, selectivity would have been poorest, and de-tuning worst, while, with looser couplings, both these things would have improved.

Thus, when we are using a coupling coil, we can produce the same effect in two ways: (i) By using close spacing and a smaller number of turns, and (ii) by using a larger number of turns, but with increased spacing between the two coils. At one time coils were constructed and mounted so that the coupling between them could be varied by mechanically shifting them closer together or farther apart. Nowadays this scheme is reserved only for very special uses in receiving sets, and coils are usually wound with the coupling fixed at the best value for the purpose in hand.

THE NEXT CIRCUIT

The next circuit to be built is shown in Fig. 7. As can be seen, it uses only one coil—that belonging to the tuned circuit—which has on it a large number of taps. There are eleven of these in all. As before,

the coil is wound with 60 turns on a 3-inch diameter former, and the variable condenser has a maximum capacity of 0.00035 mmfd. It is not necessary, therefore, to buy any new parts to build this set if the old former and tuning condenser are used. From the point of view of building up a stock of parts, however, it might be advisable to invest in a new piece of coil former and to keep the previously-wound coil, which will come in handy later.

The new coil is wound with a tap every five turns. As can be seen from Fig. 7, the tuning condenser is connected across the whole of the coil as in the previous sets. This time, however, the lead from the crystal detector to the coil is not soldered in place, but is provided with an alligator clip which allows connection to be made to any of the coil taps. The aerial also is given an alligator clip, so that it, too, may be connected to any of the taps. This makes a very flexible arrangement, which will give excellent results under any conditions. The aerial coupling arrangement is the same as that shown in Fig. 4. It is an inductive coupling, because use is made of the lower portion of the tuned circuit coil. This portion acts in exactly the same way as a separate aerial coil, and at the same time forms part of the tuned circuit coil. Selectivity may be increased and detuning avoided by using only the lower taps on the coil for the aerial. This corresponds to using a small aerial coil.

PURPOSE OF THE CRYSTAL TAP

The purpose of the tap for the detector lead is to allow the selectivity of the set to be increased still further. This makes the set much better for use in places where more than one local station comes in quite strongly, and causes interference. In addition, tapping the crystal down the tuned circuit may even increase the strength of the signals received under some conditions.

HOW IT WORKS

Some way back in this series, we mentioned the way in which the aerial, if connected at the top end of the tuned circuit, causes what is known as **damping.** In any set in which the detector and headphones are connected across the whole tuned circuit, these also cause damping. That is to say, the circuit is not able to amplify the aerial currents as much as it would if the detector and phones were disconnected. However, if this was done, we would have no means of observing the radio currents anyway! Damping of the tuned circuit by the crystal headphone connection cannot be avoided altogether, but by means of the scheme in Fig. 7 it can be greatly reduced.

If the damping is reduced, it is possible for two desirable effects to occur. First, the volume in the phones can be increased, and secondly the selectivity of the set can be greatly increased.

SHOULD NOT BE OVERDONE

Tapping the detector down the coil cannot be overdone, however, since if this is carried too far, the volume of the signals in the phones will be decreased, instead of increased. This is because then, only a small portion of the signal found across the tuned circuit is applied to the detector and phones.

Thus, in using the tappings, care should be taken to find the best adjustment for each station, if more than one can be heard. Let us consider an example we have used before. We will suppose that you are quite close to two very strong local stations, whose frequencies are not very far apart. In this case, it is almost certain that, when both are transmitting, the simpler circuits with which we have experimented will not allow the two to be separated, and no matter how much we use the tuning condenser, it is impossible to find a spot where one of the stations can be tuned in and the other out. This set will be found to be a great improvement for cases like this.

OPERATION OF THE NEW SET

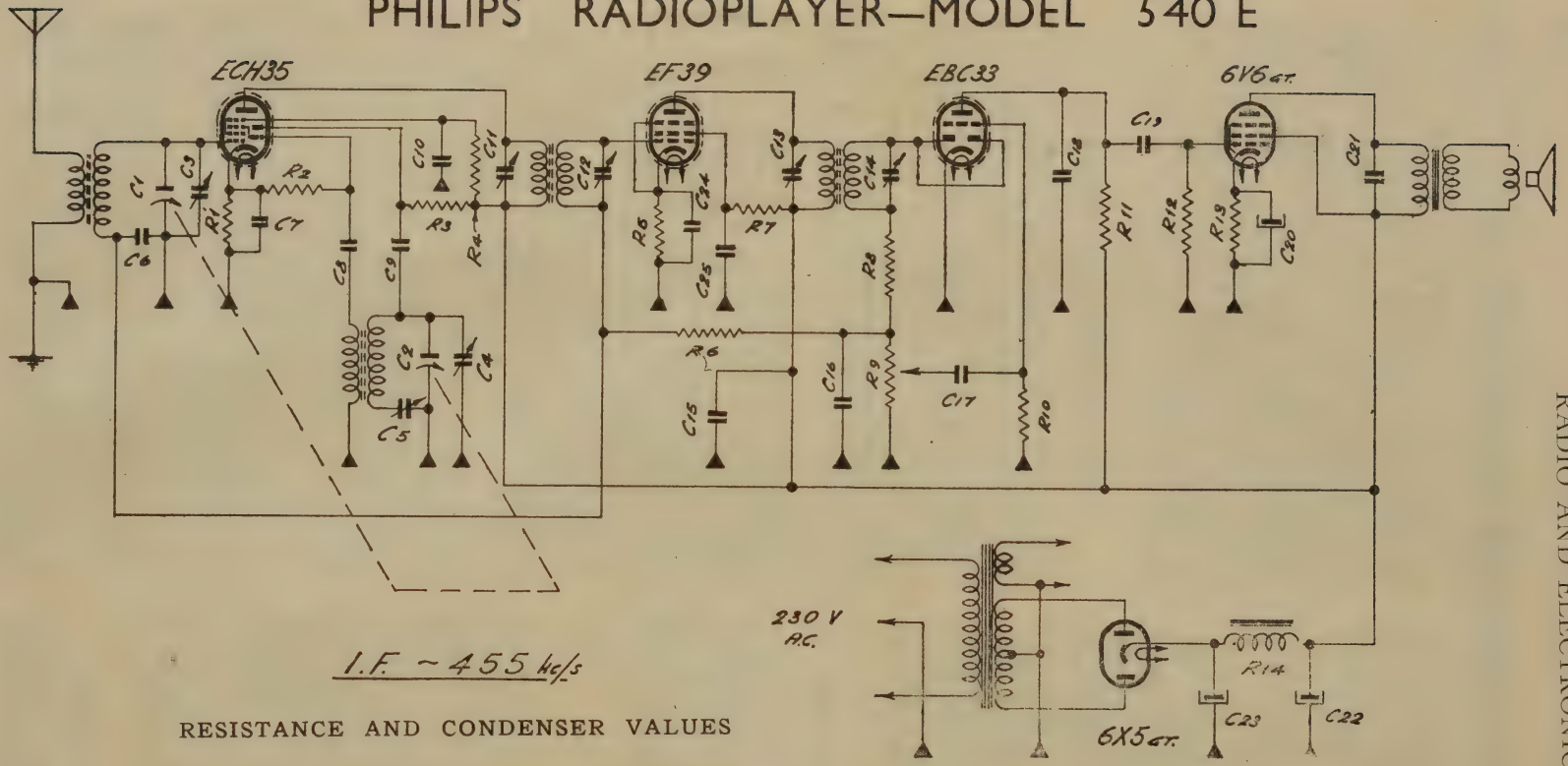
In operating this set, which has four controls as against two for the simplest set and three for the next easiest, it is absolutely necessary to work to a system if the best possible results are to be obtained. First of all, tap on the aerial at the third or fourth tap from the bottom or earthed end. This gives the same effect as an aerial coil of 15 to 20 turns, and will not produce undue detuning or damping. Now, connect the alligator clip from the crystal to the top of the tuned circuit and tune in your main station in the usual way, finding a sensitive spot on the crystal.

Next, without disturbing the crystal adjustment, transfer the crystal alligator clip to the third or fourth tap down the coil, thus putting 15 to 20 turns between the top of the coil and the crystal connection. Note whether the volume of the signal has increased or decreased, and see if re-tuning with the variable condenser now gives a slightly different setting for better results. Now, shift the crystal connection down the coil one tap at a time, re-tuning each time the clip is shifted.

The purpose of proceeding in this way is to find to what point the tapping down can be carried before it starts to reduce the volume in the phones to a level too low for comfortable listening. When this tapping point has been found, you know that, although using lower taps may increase the selectivity still further, no useful purpose can be served because so doing reduces the signal so much that it is no longer easily heard. You are now in a position to get the best out of the set under any conditions. If there is no problem of separating two nearby stations, as, for instance when only one station can be received at any time, or when one of the interfering stations is off the air, the crystal may be connected to the tap which gives the best volume. The selection of this will depend to some extent on the aerial tap which is being used, and on the particular spot on the crystal also in use.

You can see from all this that even in a crystal set quite complicated effects come into play, and that unless you approach it as an organised experiment and proceed with only one of the possible adjustments at a time, it would be quite possible for you to make adjustments for hours without really finding out the effect of each kind of adjustment on the performance of the set.

PHILIPS RADIOPLAYER—MODEL 540 E



RESISTANCE AND CONDENSER VALUES

C1	..	Gang	
C2	..	Gang	
C3	..	Trimmer	
C4	..	Trimmer	
C5	..	Padder	
C6	..	.05 Mfd.	200v.
C7	..	.05 Mfd.	200v.
C8	..	100 Mmfd.	Ceramic
C9	..	100 Mmfd.	Ceramic
C10	..	.01 Mfd.	400v.
C11	..	I.F. Trimmer	
C12	..	I.F. Trimmer	
C13	..	I.F. Trimmer	
C14	..	I.F. Trimmer	
C15	..	.1 Mfd.	600v.
C16	..	100 Mmfd.	Ceramic
C17	..	.01 Mfd.	400v.
C18	..	400 Mmfd.	Mica
C19	..	.01 Mfd.	600v.
C20	..	25 Mfd.	25v.
C21	..	.01 Mfd.	600v.
C22	..	10 Mfd.	450v.
C23	..	10 Mfd.	450v.
C24	..	.05 Mfd.	200v.
C25	..	.01 Mfd.	400v.
R1	Res.	200 Ohm	1/3 Watt
R2	,,	50K. Ohm	1/3 Watt
R3	,,	20K. Ohm	1/2 Watt
R4	,,	20K. Ohm	1/2 Watt
R5	,,	200 Ohm	1/3 Watt
R6	,,	2 Megohm	1/3 Watt
R7	,,	100K. Ohm	1/2 Watt
R8	,,	50K. Ohm	1/3 Watt
R9	,,	500K. Ohm	Control
R10	,,	5 Megohm	1/3 Watt
R11	,,	500K. Ohm	1/3 Watt
R12	,,	500K. Ohm	1/3 Watt
R13	,,	600 Ohm	1 Watt
R14	,,	1250 Ohm	Field

VOLTAGE TABLE

Valves	Plate Osc. 110	Screen	Cathode	Filament
ECH35	210	130	2.1	6.3
EF39	210	65	1.2	6.3
6V6GT	200	210	14	6.3
EBC33	20	—	—	6.3
6X5GT	225 per Plate A.C.	—	255	6.3

The voltages given in this table are the average values taken from a number of sets. The voltmeter used has a sensitivity of 1,000 ohms per volt.

The readings were taken with no signal input to the receiver, and the tuning condenser at maximum capacity. Variations in voltage readings up to 10 per cent. are permissible.

FOR THE SERVICEMAN

Coil Connections for Philips Radioplayer Model 540 E

AERIAL COIL

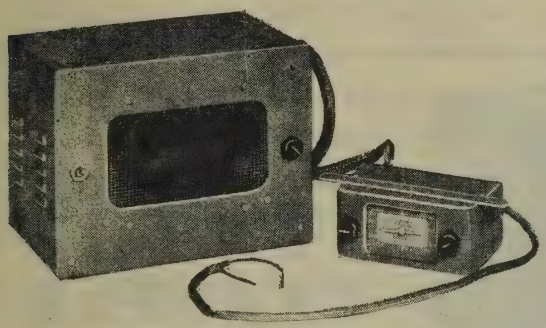
NOTE.—MKI: Dial is calibrated so that the lower frequency end is in minimum **clockwise** direction.
MKIII: Maximum **anti-clockwise** direction.

OSCILLATOR COIL

Types:
MKI : 471.14 : Red Spot.
MKIII: 471.15 : Red and White Spot.
Triode Grid Coil .. 7—1
Triode Plate Coil .. 6—5

Types:
MKI : 469.30 : White Spot.
MKIII: 469.33 : Blue and Green Spot.
Aerial Coil .. .. 6—2
Hexode Grid Coil .. 4—1

MOTOR CAR RADIO IN KIT-SET FORM



We now have kit-sets, wiring diagrams and constructional details for a 5-valve car radio which enables the home constructor to make a high-grade receiver equal in tone and performance to the imported radio.

It is made in two units—one, the small control unit, is COMPLETELY WIRED and may be fitted to the steering column or instrument panel. The second unit is the main assembly, and measures 9¾ in. x 7¼ in. x 6 in. The tube line-up, including an R.F. stage, is two 6SK7's, one 6K8. one 6Q7, and one 6V6.

By substitution of low-drain tubes, this kit would make an excellent set for boat or caravan. The two units are housed in metal cabinets handsomely finished in sprayed suede flock.

Prices for the complete kit of parts, together with further technical information, will be given on request. The following kits are also available:—

5-VALVE PORTABLE, including cabinet, which is available in any of five colours, the measurements of which are 12½ in. x 10 in. x 7 in. ..... PRICE £15/-/-

5-VALVE BROADCAST ..... Less cabinet £12/10/-

Small cabinets in plain wood £1/5/-

7-VALVE ALL-WAVE, including amateur band..... Complete £20/5/-

9-VALVE ALL-WAVE RECEIVER, including amateur band, are also available, but the price will depend on the speaker required.

For full information write to

WEBB'S RADIOS

11 Wellesley St. E., Auckland, C1.

Letters to the Editor

THE *RADIO AND ELECTRONICS* 10-METRE CONVERTER

Since the appearance of the July, 1946, issue of *Radio and Electronics* containing the article on our 10-metre converter using an infinite impedance mixer, no R.F. stage, a 6AC7/1852 I.F. amplifier on 4 mc/sec., and a cathode follower output stage, we have learnt that many people have been openly sceptical of the performance claimed for it. Now that "10" is starting to come in again for the summer months, we find there is renewed interest in our design, and in order to confound the sceptics we offered our prototype to one of them to test for himself against a standard commercial communications receiver which has two stages of R.F. amplification. So complete was our chosen sceptic's conversion to our own ideas about the converter (no pun intended) that we were sure that readers would find his comments interesting. Here they are:—

Sir,—I have just spent a most interesting and instructive morning in comparing the performance of the "Radio and Electronics" 10-metre converter with that of a conventional communications receiver. The latter has two stages of R.F. amplification, and can be termed representative of its class.

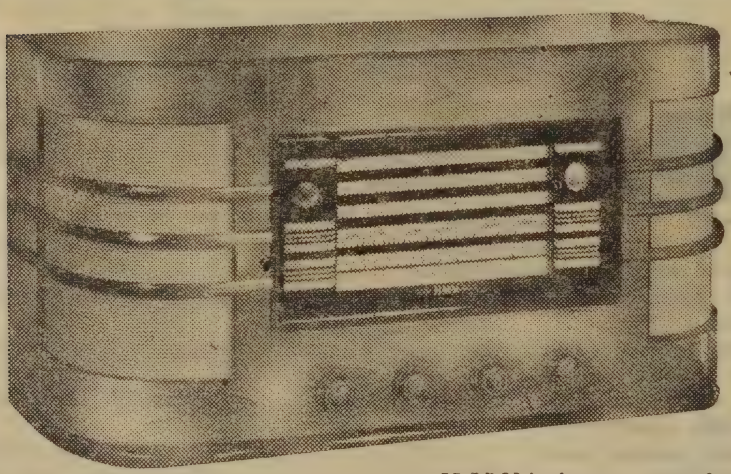
The converter was compared with the receiver used alone, the same aerial being used in each case, and there was no doubt whatever of the superiority of the performance of the converter.

The most striking feature of the converter's performance is the almost complete absence of "mixer hiss"—a very important point when one is attempting to copy very weak signals.

Although no measurements were made, the inferior performance of the communications receiver was readily perceptible by ear, which indicates that the improvement must be several db. at least.

Other notable features of the converter's performance were its selectivity and its image rejection. Of course, the selectivity should be as good as that of the receiver used with it, but the additional advantage of high oscillator stability (which is definitely achieved in your design) makes it possible, if desired, to use the full selectivity of the associated receiver. Poor oscillator stability in the converter would prevent this.

Experience has convinced me that, while it is quite a simple matter to achieve considerable amplification at signal frequencies on the 10-metre band, it is practically impossible to do so without generating additional noise. I must admit that your scheme of omitting R.F. stages altogether, and of using a very low noise mixer, did not at first seem practicable to



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His Master's Voice

me, but the tests I have just carried out find me as completely converted as I found the 10-metre signals!

The fine performance of your converter makes it well worth recommending, but I would like to point out to intending constructors that, on these frequencies, any receiver will be only as good as its aerial system allows it to be. Even a few decibels of aerial gain in the desired direction make all the difference, and more than repay the man who has worked hard to obtain them.—I am, Sir,

N. B. JOHNSTON,
ex-ZL2PL.

PUBLICATIONS RECEIVED

(*Continued from page 39*)

G.E. ELECTRONIC TUBE MANUAL

In the Trade Winds Section of our last issue, we made reference to the G.E. Tube Manual submitted by the National Electrical and Engineering Co., Ltd. We wish to advise readers that the full name of the Company concerned was omitted. This should have read: "The General Electric Company of America."

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TUBE DATA

(*Continued from page 23*)

This can be done by using a good layout and by shielding the input and output circuits. This will be necessary because of the very high valve gain, and because the grid-plate capacity, though small, is not altogether absent.

CLASSIFIED ADVERTISEMENTS

Rates are 3d. a word, with a minimum charge of 2/-. Advertisements must be to hand in this office not later than the fifteenth day of the month in order to be published in the issue appearing about the middle of the following month.

While all care will be taken, no responsibility can be accepted for errors. Advertisements should therefore be submitted either typed or printed in block letters.

WANTED.—Working Instructions for "Calstan" 483 Analyser; purchase or hire. T. H. Baker, 23 Rolleston Street, Timaru.

This Month's "Q"-QUIZ

Inductances

QUESTION:

Why is it necessary to use different types of coils with various types of mixer or oscillator tubes, and how may it be ascertained whether the oscillator tube is functioning correctly?

ANSWER:

The amplitude of oscillation in any converter tube is normally stated by the manufacturer in terms of grid current with a specified H.T. voltage and grid resistor. The coil used must therefore be designed to enable the tube to operate within the grid-current limits set by the manufacturer.

The correct operating conditions may be found by inserting a meter in series with the grid leak.

Various types of oscillator tubes have different mutual conductances, so that oscillator coils must be designed to suit particular conditions.

Inductance Specialists indicate by means of a letter following the coil serial number the coupling, and hence the type of converter tube to be used:—

Letter X = 6K8.

Letter Y = 6A8, 6A7G, or tubes of similar characteristics.

For example, coil 51BX indicates unshielded broadcast coil; B for 385 mmfd. gang and X for 6K8 tube.

INDUCTANCE SPECIALISTS,

202 Thorndon Quay, Wellington

FREQUENCY MEASUREMENT

(*Continued from page 37*)

lator. Since the load resistor is in series with the load resistors of both tubes in the multivibrator, this 1000 kc/sec. voltage is applied to the plate circuit of each tube. It will be noted that the locking voltage is fed in phase to the two plates simultaneously. This connection ensures that the multivibrator is much more readily locked by even harmonics than by odd ones.

WIDE-BAND AMPLIFIERS

(*Continued from page 32*)

introduction to an extremely interesting subject which will continue to find increasing application in many fields. Those wishing to pursue the subject further could usefully consult the chapters on Video Amplification in Fink's *Principles of Television Engineering* and Zworykin and Morton's book on the same subject. Both these books have excellent bibliographies, giving the references of a large number of the original papers on wide-band amplification.

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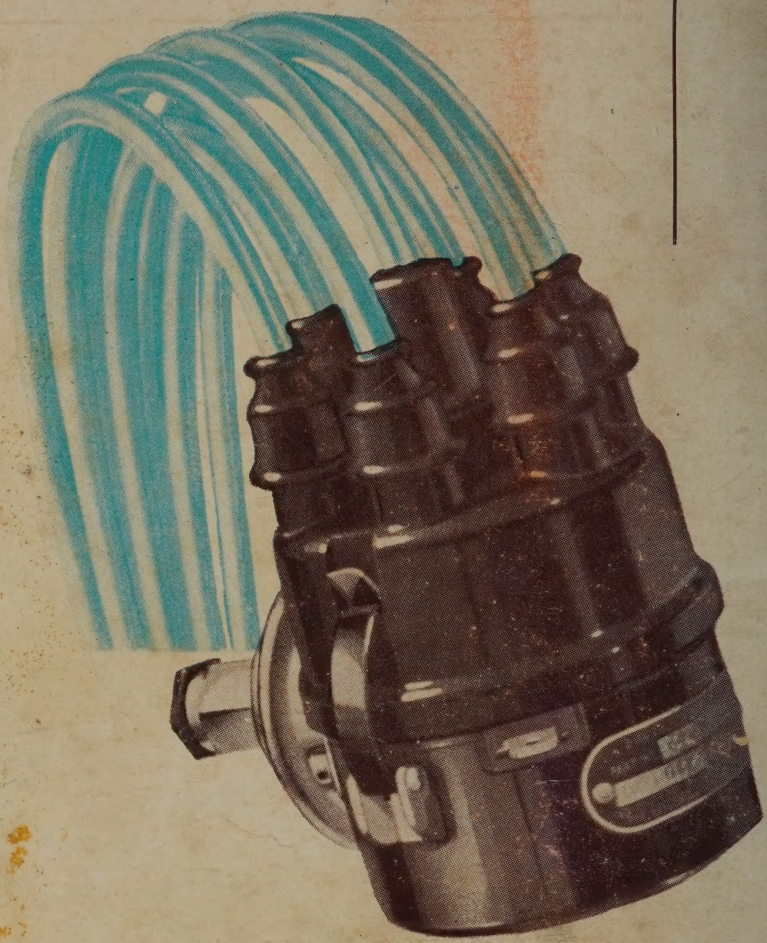

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